# The World Whole: An Environmental History of Japanese Space Power

The fox knows many things, but the hedgehog knows one big thing.

- Archilochus[1]

## Introduction: Grand Narratives, Modernity, and Environmental Change

The past is made of stories, or at least history is. Walter Benjamin once wrote that "where *we* see the appearance of a chain of events, *he* [The Angel of History] sees one single catastrophe, which unceasingly piles rubble on top of rubble and hurls it before his feet. He would like to pause for a moment so fair, to awaken the dead and to piece together what has been smashed."[2] Those who write that past under the Angel's gaze organize this chaotic, formless mass of occurrences, peoples, and interactions into broad narrative strokes made up of discreet causative events, heroes and villains, and conflicts.[3] These stories help historians and readers to give meaning to the chronicles, but they also inevitably distort the past, twisting it to fit into more definite narrative patterns. My purpose throughout writing this thesis has been to deconstruct particular stories, but hopefully to do so in a provocative and useful, rather than destructive, way. In dissolving the boundaries, categories, and relationships that certain narratives rely on, I want to offer a richer collection of stories about the past than these constrains allow.

That being said, the narrative form is not altogether escapable for reasons of clarity, cohesion, and necessity as much as evocation and readability. I do not want to eschew it

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[1] Isaiah Berlin. *The Hedgehog and the Fox: An Essay on Tolstoy's View of History*. 2nd Edition. Ed. Henry Hardy (Princeton: Princeton UP, 2013). 1.

[2] Walter Benjamin. "On the Concept of History." Trans. Dennis Redmond. Transcribed by Andy Blunden. *Marxists.org*. 2005. https://www.marxists.org/reference/archive/benjamin/1940/history.htm.

[3] The standard work on narrative construction in history is Hayden White's. See *Metahistory: The Historical Imagination in Nineteenth-Century Europe*. 40th Edition. First published in 1973 (Baltimore: John Hopkins UP, 2014).

altogether, but to critically engage it, to place these stories in the context of Japan's modern engagement with outer space, and read between their lines and pull on the various frayed threads to work towards a more robust, but pluralistic, picture of the evolving relationship(s) between humans, technology, and nature.

William Cronon's famous 1992 essay "A Place for Stories: Nature, History, and Narrative" helped push environmental historians toward a "cultural turn" by acknowledging the important subjectivities that define the perimeters and nodes within and around which they tell their stories.[4] Distinguishing two broad narrative patterns in the historiography of the Dust Bowl, Cronon typifies these histories as "progressive" or "declensionist." Progressive narratives emphasize human ingenuity and achievement, spinning triumphalist tales of human overcoming of a harsh and antagonistic natural landscape, ultimately leaving behind a happier and healthier human population undergirded by a tamed environment. Declensionist narratives, on the other hand, slope downwards towards tragedy, emphasizing humans' failure to accommodate themselves to a balanced and fragile ecosystem, irreparably damaging it and causing all too social "natural disasters."[5] In this latter type, it is important to recognize the theme of *destruction*; "nature" is defined as balanced, stable, and cyclical, while human intervention is the motor of linear change. In the process of dominating the landscape, subduing it and reorganizing its components "productively" according to human needs, "nature" is destroyed and strikingly "unnatural" disasters are made possible.[6]

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[4] William Cronon. "A Place for Stories: Nature, History, and Narrative." *Journal of American History*. Vol. 78 Issue 4 (1992). 1347-1376. For an insightful historiography that pays close attention to these debates in the 1990s, see Andrew C. Isenberg. "Introduction: A New Environmental History." *The Oxford Handbook of Environmental History*. Ed. Andrew C. Isenberg (New York: Oxford UP, 2014). 1-20.

[5] Cronon. "A Place for Stories," 1352.

[6] Cronon. "A Place for Stories," 1357-1364.

These narratives are also essentially stories about modernity. Pre-modern peoples, it is often imagined, lived in more harmony with nature and were less disruptive. This story is the classic Edenic narrative; modernity, broadly writ as science, capitalism, and industrialism, has alienated people from nature. Although the two narratives can be contrasted in terms of their *values*, their underlying descriptive assumptions form a much larger grand narrative. *Modernity*, they have it, can be understood as *the linear process through which humans have used technology to increasingly control nature*. In progressive narratives, this control is colored positively, as an achievement, while in declensionist ones, control is as vilified as nature is victimized through humans conquest, "rape," and destruction. These narratives share a common ontology, a set of discreet, bounded entities: humans, technology, and nature; they ascribe distinct roles to each: agent, instrument, and object; and they organize the history by a single, broad, parameter: control over time.

Cronon rightfully sees the dichotomous values both narratives attach to their histories, but an overriding focus on moral value overshadows the underlying structures that make either narrative make sense in the first place. Cronon's emphasis on value in general allows one not only to overlook the existence of that common ground, but also to overlook substantial questions regarding their problematic nature. Narratives may change their moral characteristics over time, but often over a descriptive substructure internalized as common sense.

**Japan, Environmental History, and Outer Space**

Emerging in the 1970s, environmental history came into its own by the early 1990s. In that year, the *Journal of American History* held a field-defining roundtable that introduced the nascent subject to the mainstream historical community. In this roundtable, particularly circling

around the essays by William Cronon and Donald Worster, a debate emerged regarding the promise and future of environmental history. For Worster and likeminded colleagues, it was important that environmental historians not sell themselves short and "nostalgically" revert to the constructivist approaches of the social historians. Nature, he had it, was a real and powerful force independent of culture and the human mind. Historians must not, against Cronon, "place nature within history," but must rather "see beyond culture" and contextualize human activity *within* nature and the material world. Cronon, wishing to put environmental history in closer dialogue with other historians' work, wished, alongside Carolyn Merchant, that the new field adopt the analytic categories of gender, race, and class to ground human engagement with the natural world.[7] Over time, the debate has become seen as one between materialist and social constructivist approaches.

Ever since, environmental historians have arguably worked to give both sides their equal weight, adopting "hybridity" as a keystone concept to explain the "long and tangled history" between social and natural forces.[8] Nature mattered in history, perhaps even had agency, but no social or natural development worked independently, and both were needed to understand each other. As Paul Sutter's recent review put it, the second generation of environmental historians saw "the world with us."[9] Most recently, two themes especially have been pushing the field forward into new, exciting territory. First, as exemplified by Timothy LeCain's recent tour-de-force *The Matter of History*, neo-materialist approaches that emphasize the hard physical basis of

[7] See Donald Worster "Transformations of the Earth: Toward an Agroecological Perspective in History." 1087-1106; "Seeing Beyond Culture." 1142-1147; William Cronon. "Modes of Prophecy and Production: Placing Nature in History." 1122-1131; Carolyn Merchant. "Gender and Environmental History." 1117-1121. *Journal of American History*, Vol. 76, No. 4 (1990).
[8] See Richard White. "From Wilderness to Hybrid Landscapes: The Cultural Turn in Environmental History." *A Companion to American Environmental History*. Ed. Douglas Cazaux Sackman (Oxford: Wiley-Blackwell, 2010). 187.
[9] Paul Sutter "The World with Us: The State of American Environmental History." *Journal of American History*, Vol. 100, No. 1 (2013). 94-120.

all history has decentered the human mind as the force of change in history. Rather, the material world has been reconfigured as an active force, one that is in constant and unstable flux. For LeCain, environmental historians have to forget about "nature," as such, and focus on the material environment we find ourselves in, and it is this environment and our engagement with it that ought to be at the forefront of environmental historians' work.[10]

Relatedly, the notions of *embodiment* or *embeddedness* are beginning to find a central place in environmental historians' basic concepts. In a short but surprisingly influential 2005 essay (only three pages in length), Linda Nash argues that we must not obsess over the "agency of nature," but instead focus instead on "putting the human mind back in the world." If we understand agency as something "dispersed among humans and nonhumans," the individual human mind, the source of intentionality, is grounded in its relationship to the physical objects around it. LeCain's work draws out much from putting these ideas in conversation with advances in cognitive philosophy, linguistics, micro-ecology, and epigenetics. Human nature is not what we have thought.[11]

In another work, while Mark Fiege defines nature as "the omnipresent substance of reality," he also breaks new ground in contextualizing the ideas of those like New England colonists and Abraham Lincoln in their embodied experiences in the material world. Likewise, another influential work by Thomas Andrews coined the term "workscape" to explore how the political consciousness of striking miners in Colorado was formed within the hybrid environment of coal mines as workers physically engaged with the world around them. Whether it be with explicit regard to human nature, or more broadly, the material world has become inescapable,

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[10] Timothy J. LeCain. *The Matter of History: How Things Create the Past* (Cambridge: Cambridge UP, 2017).
[11] Linda Nash. "The Agency of Nature or the Nature of Agency?" *Environmental History*, Vol. 10 Issue 1 (2005). 67-69.

and environmental historians have done an exemplary job in integrating this world within the uneven terrain of race and class so as to communicate with the discipline. In many ways, environmental history has become less a distinct subject area than a fundamentally important way of doing any history.[12]

Scientific knowledge has played a key role in this material turn, but as Gregg Mitman's reply to Paul Sutter shows, there remains a divide in how to approach scientific inquiry. Generally, constructivist and realist approaches are in tension with one another, as science (at least certain sub-disciplines of it) is understood both as a realm of socially contextualized human ideas as well as one of, maybe th*e most*, important interdisciplinary tool to understand environmental history. Overall, the best work of environmental historians is able to combine both perspectives, both using science as a tool as well as critically engaging with it. The work of those like Linda Nash and Edmund Russell, the latter promoting what he calls "evolutionary" history, has catalyzed an increasing dialogue between the natural sciences and history, while never losing sight of how humans construct knowledge.[13]

In this thesis, I will largely adopt the thrust of the views described above, effectively putting them to a rigorous test in explaining issues that have not yet been studied extensively by historians, such as urban heat islands, the history of meteorology, and space history. Using these background methods, I wish to push the field further in the direction they lead, adopting an interdisciplinary approach that effectively disperses historical inquiry across the realm of human

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[12] Mark Fiege. *The Republic of Nature: An Environmental History of the United States* (Seattle: Washington UP, 2012). 10; Thomas G. Andrews. *Killing for Coal: America's Deadliest Labor War* (Cambridge: Harvard UP, 2008). Sutter gives a much more extensive bibliography on these trends in his review essay.

[13] See Gregg Mitman's reply to Sutter: "Living in a Material World," *Journal of American History*, Vol. 100, No. 1. (2013). 128-130, as well as Edmund Russell. "Evolutionary History: Prospectus for a New Field." *Environmental History*, Vol. 8 No. 2 (2003). 204-228; Linda Nash. *Inescapable Ecologies: A History of Environment, Disease, and Knowledge* (Berkeley: California UP, 2006). For an overview of the realist/constructivist debate, see Michael Lewis "And All Was Light? – Science and Environmental History." *The Oxford Handbook of Environmental History*. 207-226.

knowledge, not allowing it to settle comfortably in any disciplinary milieu. As such, this thesis will range widely across, and at times deeply within, the applied physical sciences, philosophy, critical theory, sociology, psychology (and in the final chapter, even science-fiction). Once historians lose a staid sense of self-identity, the limits for what history can be open up enormously.

In a more limited way, I also wish to engage with and intervene in the environmental historiography relating to Japan. Environmental historians working on Japan have contributed powerfully not only to our understanding of Japan's relationship to the natural world, but also the human relationship more broadly. Classic works in history and anthropology have explored both Japan's material and cultural engagement with nature, and more recent literature has contributed to such key themes as the growth of environmentalism, Japan's relationship with the animal world, and the development of ideas about nature.[14] One particular theme that has gotten great attention in recent years is the *convergence* between early modern Japanese and European relationships with nature.[15]

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[14] For some classic, landmark works, see Tessa Morris-Suzuki. "Concepts of Nature and Technology in Pre-Industrial Japan." *East Asian History*, Vol. 1 (1991) 81-97; Conrad Totman. T*he Green Archipelago: Forestry in Preindustrial Japan* (Berkeley: California UP, 1989); *Japanese Images of Nature: Cultural Perspectives*. Ed. Pamela J. Asquith & Arne Kalland (London: RoutledgeCurzon, 1997), especially the editors' introduction "Japanese Perceptions of Nature: Ideals and Illusions," 1-35; Margaret McKean. *Environmental Protest and Citizen Politics in Japan* (Berkeley: California UP, 1981). For more recent literature from active scholars, see especially Brett L. Walker. *Toxic Archipelago: A History of Industrial Disease in Japan* (Seattle: Washington UP, 2010); *The Lost Wolves of Japan* (Seattle: Washington UP, 2005); *The Conquest of Ainu Lands: Ecology and Culture in Japanese Expansion, 1590-1800* (Berkeley: California UP, 2001); Ian Jared Miller. *The Nature of the Beasts: Empire and Exhibition at the Tokyo Imperial Zoo* (Berkeley: California UP, 2013); Julia Adeney Thomas. *Reconfiguring Modernity: Concepts of Nature in Japanese Political Ideology* (Berkeley: California UP, 2001); Robert Stolz. *Bad Water: Nature, Pollution, and Politics in Japan, 1870–1950* (Durham: Duke UP, 2014). For an important edited collection, see Ian Jared Miller, Brett L. Walker & Julia Adeney Thomas. *Japan at Nature's Edge: The Environmental Context of a Global Power* (Honolulu: Hawaii UP, 2013).

[15] See Julia Adeney Thomas. "Reclaiming Ground: Japan's Great Convergence." *Japanese Studies*, Vol. 34 Issue 3 (2014). 253-263. Federico Marcon's own book is also a fabulous approach to the issue of convergence. *The Knowledge of Nature and the Nature of Knowledge in Early Modern Japan* (Chicago: Chicago UP, 2015). Stolz, Miller, and Marcon also wrote articles within the same issue of *Japanese Studies* as part of a roundtable on "Japan's Convergence with the West: How Similar Approaches to Nature Created Parallel Developments." Thomas borrows the term "great convergence" from a conference paper that was later published in Japanese by Brett

According to the "Great Convergence" paradigm supported by Julia Adeney Thomas in a 2014 article, the longstanding problem concerning how Japan was able to so successfully adapt and modernize at the end of the 19th century cannot be answered by Japan's long history of "imitation." Rather, Japan and Western Europe, especially Britain, underwent remarkably similar development at opposite peripheries of the Eurasian continent. Specifically in Thomas' outline, Japan and Western Europe both came to invent novel forms of engagement with nature, at material, social, and conceptual levels. Both conceived of nature as a resource within a political economy of nature by the early 18th century, and both adopted technological means of controlling nature to service state ends. Because Japan and Western Europe independently converged on similar relationships with the environment, Japan was uniquely able to modernize in the face of Western imperialism, unlike China, and become the only non-western Great Power. Japan and the West eventually confronted each other in the 20th century as both ran into each other as they colonized the Eurasian landmass.

In spite of its framing as an anti-Eurocentric narrative, the convergence story merely reinvigorates the same tropes that decades of global history has been so successful in dissolving and undermining. "The rise of the West" is simply ill-conceived, ignoring the global connections that underwrote the development of capitalism and industry in Western Europe. Rather than helping to dissolve the Eurocentric basis of history and the social sciences, the convergence narrative merely falls into a "model minority" trap, keeping intact all the same Eurocentric misconceptions and simply adding in a "Japanocentric" element. Rather than appreciating the world-system of the early modern period, the convergence narrative just supplements Western

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Walker. "Ijin Naru Shūren: Nihon Ni Okeru Shizen Kankyō No Hakken." Transl. Fukuda Takeshi. *Nihon No Shisō Volume 4: Shizen To Jin-i*. Ed. Karube Tadashi et al (Tokyo: Iwanami Koza, 2013). 259-291; Thomas, "Reclaiming Ground," 253-254.

exceptionalism with Japanese exceptionalism.[16] Instead of relying on this exceptionalist convergence narrative that seems to have some popularity, this thesis will instead both work to dissolve the narrative of human control of nature in the first place, in either Europe or Japan, and reassert the importance of modernity in Japanese environmental history as a dramatic and sudden shift in Japan's relationship with the natural world that accompanied its engagement with the West in the late 19th century.

In addition to the immense and provocative literature on environmental history, I will engage with the much more limited work that has been done on space history and those related disciplines that have studied human interaction with outer space. For whatever reason, space history remains a relatively niche topic. Within this rarefied sub-discipline, the majority of work naturally has focused on the United States and to a lesser extent the Soviet Union, with only a handful of books and articles devoted to Japan.[17] That being said, outer space is a good setting and framework not only because of this relative lack of attention, but also because there are several good reasons for paying more attention.

First, humans' relationship to outer space has been fundamental to modernity in the 20th and 21st century. So much of what has happened in terms of globalization, communications revolutions, and modern technology has depended on humans' ability to take advantage of the near-Earth orbit for satellite infrastructure. Not only have these changes been fundamental to modernity broadly, but they have they have been of great importance specifically to the human

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[16] For an attempt at a non-Eurocentric overview of modern world history, see Robert Marks. *The Origins of the Modern World: A Global and Environmental Narrative from the Fifteenth to the Twentieth Century*. 3rd Edition (Lanham: Rowman & Littlefield, 2015). Marks relies heavily on two classic works that have shaped the field: Kenneth Pommeranz. *The Great Divergence: China, Europe, and the Making of the Modern World Economy* (New Haven: Princeton UP, 2000); Andre Gunder Frank. *ReORIENT: Global Economy in the Asian Age* (Berkeley: California UP, 1998). The terminology of "world-system" originates with Immanuel Wallerstein's multi-volume opus *The Modern World-System*. More recently, see Immanuel Wallerstein. *World-Systems Analysis: An Introduction* (Durham: Duke UP, 2004).

[17] For some works on Japanese space history, see footnote 298.

relationship to the Earth environment. Remote sensing, satellite meteorology, and earth photography have allowed scientists and the public to understand the Earth in novel ways and at profoundly larger scales. Outer space, then, has been fundamental to *environmental modernity* especially, and the environmental history of the last century would be incomplete without integrating outer space.

Moreover, outer space offers a distinctive setting in which to look at thematic issues already of interest to environmental and other historians, such as the geopolitical-legal transformation of the orbital landscape since the 1950s; the cultural history of human imagination of outer space; or the history of exploration and its ties to science and politics. Given the immense place outer space has in American culture specifically, it is strange indeed that it occupies such a marginal historiographical position, although the work that has been done will inform my work throughout.

The connections between outer space and Earth can be reframed using a novel theoretical apparatus. Two concepts will be important: Earth-space and space power. The boundary between earth and outer space is porous and there exists a constant and ever-present "material dialectic" between Earth and space that connects the two in a tight system of interpenetrations.[18] *Earth-space is the material, spatial, and discursive interconnections that inextricably tie Earth to its space environment*. Additionally, "what happens at the intersections of terrestrial and outer space establishes social power."[19] Nayef Al-Rodham usefully overviews the ways that scholars have discussed "space power" in the literature, and he seeks to provide a more inclusive definition, arguing that space power is essentially the ability to "use space" to enhance a list of geopolitical

[18] Peter Dickens and James S. Ormrod. ""Introduction: The Production of Outer Space." *The Palgrave Handbook of Society, Culture and Outer Space*. Ed. James S. Ormrod and Peter Dickens (London: Palgrave Macmillan, 2017). 4.
[19] Ibid. 2.

"capacities." Like previous definitions, this definition is vague in its verbs and prepositions; notions of "using" or "employing" outer space or implementing power "through" or the power "of" outer space have proliferated.[20] Here, *space power will be defined as the ability to take advantage of interchanges within Earth-space.*

Given this definition, it is useful to divide space power into three "tiers." The first tier at which space power is enabled is the control and manipulation of extraterrestrial resources that enter Earth naturally through the atmosphere. Most importantly, this includes solar radiation, which will be the topic of my first chapter. At the second tier, humans interact with the exchanges of information, and the matter which contains that information, across Earth-space. This tier most importantly includes satellite-based forms of knowledge, which will be the focus of Chapter Two. Finally, at the third tier, human bodies themselves interact with the outer space environment. At this level, humans' (and other organisms') sensory capabilities and physical limitations become relevant, and it will be those potentials and constraints that will guide Chapter Three.

The seemingly unnatural inclusion of space resources and the first tier within space history is important for a few reasons. First, on a purely analytic level, this inclusion is implied given the definition of space power as based on Earth-space exchanges. Previous scholarship on outer space or the sun that speaks to these interactions, even those scholars who adopt explicitly realist frameworks, have often relegated their discussion of solar radiation to cultural beliefs and human imagination.[21] My focus on the material interaction with solar energy is thus an important

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[20] Nayef R.F. Al-Rodham. "The Meta-Geopolitics of Outer Space." *The Palgrave Handbook of Society, Culture and Outer Space*. 139-145.

[21] See for example James S. Ormrod and Peter Dickens. *Cosmic Society: Towards a Sociology of the Universe* (New York: Routledge, 2007). Simon Carter discusses the lack of materiality with which the relationship between humans and the sun is often discussed, and his own book is the exception that proves the rule: *Rise and Shine: Sunlight, Technology and Health* (Oxford: Berg, 2007). 1-10.

corrective here. On another level, all interactions with outer space in the last century were necessarily precedented by those interactions which took place on Earth which contextualize humans' motivations for further engagement and understandings of outer space. Finally, it will become highly important in the next chapter to "place" solar energy in the larger, cosmic geographic context in order to understand Japan's relationship to solar heat and light. Without placing the sun in outer space, this history would miss out on an illuminating opportunity to contextualize human activity within the solar system.

In recent years, there has in fact emerged an exciting range of work on the environmental history of outer space. Three scholars feature most prominently. Neil Maher's *Apollo in the Age of Aquarius* attempts to "ground" the Apollo program in the racial, gender, war, and environmental politics of the 1960s and 1970s. In these frameworks, Maher explores the material implications and bases of NASA's programs as they related to intercity environmental racism, the gendering of female bodies, and the Cold War politics of remote sensing. More radically, Lisa Ruth Rand's work has explored the making of "space junk" during the Cold War, conceptualizing the near-Earth orbit as a borderland that was both constructed by human activity and reciprocally influenced geopolitics on the planet. Finally, Dagomar Degroot, both in a 2017 article and an upcoming book project: *Civilization and the Cosmos*, has attempted to give *agency* to the outer space environment, showing how cosmic events observed as far away as Jupiter have pushed humans toward new insights, concepts, and even economic programs.[22]

[22] Neil Maher. *Apollo in the Age of Aquarius* (Cambridge: Harvard UP, 2017). See also Maher's earlier "On Shooting the Moon." *Environmental History*, Vol. 9 No. 3 (2004). 526-531.; Lisa Ruth Rand. "Orbital Decay: Space Junk and the Environmental History of Earth's Planetary Borderlands." PhD Diss. University of Pennsylvania (2016); "Falling Cosmos: Nuclear Reentry and the Environmental History of Earth Orbit." *Environmental History*, Vol. 24 Issue 1 (2019). 78-103; Dagomar Degroot. "'A Catastrophe Happening in Front of our Very Eyes': The Environmental History of a Comet Crash on Jupiter." Environmental History, Vol. 22 Issue 1 (2017). 23-49. For a description of his manuscript project, see "Projects." Dagomar Degroot. https://www.dagomardegroot.com/projects.html. In addition to this research, see Margaret A. Weitekamp. "Critical Theory as a Toolbox: Suggestions for Space History's Relationship to the History Subdisciplines." *Critical Issues in the History of Spaceflight.* Ed. Steven J. Dick

While opening exciting new avenues, each of these works has been somewhat narrow in its conceptualization of what outer space can bring to environmental history. While the three tiers introduced earlier allow for a loose structure, each chapter will use outer space in a variety of very different ways to show a larger scope and promise that the endeavor of bringing environmental history outside the planet can hold. Outer space has been at once a source of material exchange with the Earth environment, a uniquely situated epistemological vantage point, an "extreme environment" itself with distinct properties, and a cultural landscape soaked through with human ideologies.

**Structure and Outline**

Through an analysis of Japanese space power in the 20th century, I hope to deconstruct the reductive narrative of modernity that imagines humans to progressively gain more control over nature over time. I will also address four sub-themes. First, I want to *scientize* this history by demonstrating the plural methodological approaches that historians can take to use and analyze scientific knowledge and open up avenues of inquiry. Second, this thesis will *materialize* this history by integrating recent materialist theories in order to give a fair amount of time to discussing the material powers at work throughout. Additionally, I want to call attention to ways that materialist theory might be reconciled with constructivist ideas and extended. Third, I want to *spacify* this history by demonstrating the important ways that outer space is connected with

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and Roger D. Launius (Washington D.C.: NASA, 2006); K. Jan Oosthoek. "New Horizons: Space, a New Frontier for Environmental Historians." *Environmental History Resources*. 16 July 2015. https://www.eh-resources.org/space-new-frontier-for-environmental-historians/; Roger D. Launius. "Writing the History of Space's Extreme Environment." *Environmental History*, Vol. 15 No. 3 (2010). 526-532. The American Historical Association also held a session on this topic in 2015. Jacob Ingram. "Finding New Space in Space: Reflections on Environmental and Outer Space History at AHA 2015." *Perspectives on History: AHA Today*. 15 January 2015. https://www.historians.org/publications-and-directories/perspectives-on-history/january-2015/finding-new-space-in-space-reflections-on-environmental-and-outer-space-history-at-aha-2015.

Japan's modern engagement with the natural world. Finally, it is important to *globalize* this history by firmly setting Japan's history within the global context of modernity, paying close attention to both the ways Japan received *and contributed* to the modern world.

Chapter One describes Japan's interactions with solar radiation in the 20th century, specifically relating to the development of Tokyo's urban heat island over the *longue duree* of the century, as it developed through the destruction of natural green and watery landscapes. This earthen material was gradually replaced with a built environment of impermeable manmade material, especially concrete after World War II. Humans did not necessarily gain control over natural forces over time as Japan modernized, but that in important ways the environment gained control over humans' lives as they lost control of the material forces around them.

Chapter Two turns to the second tier to analyze the epistemic effects of satellites on Japanese and global meteorology and remote sensing. I first give a genealogy of quantification and "synopticism" in Japanese meteorology and the epistemic context that satellites were fit into before turning to the question of incommensurability between scientific and lay, "grounded" knowledge of weather. These incompatibilities show that control requires a complex mediation between different forms of knowledge, and the advance of space power and knowledge in the 20th century did not ensure control over weather events, in some ways worked against itself, and even amplified the danger of weather risks. From this, I turn to a more limited case of the 1995 Kobe Earthquake to critique the subjectivities involved with InSAR satellite analyses of the "natural disaster," destabilizing progressivist narratives of the growth of scientific knowledge and the ability to understand and cope with nature using space power.

In Chapter Three, in the third tier, I turn to the porous boundaries between society, nature, and technology as they (dis)appear in Japan's space flight endeavors of the 1990s. The

aforementioned grand narratives falsely rely on stable notions of these discreet entities. The phenomena of overview effects, space life science, and robotics reveal both the ways in which modernity brought these three categories together relationally to push history forward as well as the dissolutions these three events involved. As humans went into space, they experienced cognitive shifts when looking back upon the "blue planet" and saw new connections between humans and nature, a transcendent experience enabled by complex configurations of biology, Earth-space, technology, and social discourse. Similarly, the study of life in space, specifically during the Frogs in Space experiment conducted by Toyohiro Akiyama aboard the *Mir* space station, transformed biological material into epistemic tools to understand nature even as that technology itself remained as vital organisms. Finally, the tele-operational robots Japan's space agency worked on in the late 1990s merged the agential potential of humans and machines together into a cyborgic whole as Japan confronted the harsh physical and cultural environment of outer space.

In one way, dissolving the grand narrative of human-nature interaction is really only a tool, a sturdy nail to hang everything else on. It is less *that* this grand narrative is an unstable myth; I believe this is well understood by almost all interested parties to some extent. It is more *how* one can uncover this truth, and the important points about historical methodology, agency, and materiality along the way. As Archilochus wrote, "the fox knows many things," and this project is nothing if not a "fox" approach, "seizing upon the essence of a vast variety of experiences and objects for what they are in themselves… [a vision] compounded of heterogeneous elements," all to substantiate a critical gaze upon the hedgehog's grand narrative.[23]

[23] Berlin. *The Hedgehog and the Fox*, 2-3.

# Modernity's Oven: The Making of Tokyo's Urban Heat Island

## Introduction: The Science of Urban Heat Islands

On a clear midnight in March, 1939, two Japanese researchers, Fukui and Wada, conducted a landmark study on temperature gradients between Tokyo's urban center and its suburban surroundings, riding motorcars between the two locales. A leading geographer, Fukui's work had already begun to pave the way for the development of climatology in Japan. Just the previous year, he had published 556 pages that were foundational to the discipline's growth, and in 1939 he would gain the lectureship in climatology at Tokyo Bunrika University.[24] Publishing their results in 1941, Fukui and Wada reached the conclusion that "the city is much warmer than its suburbs… The difference in temperature between the city and its environs is as much as 5.0°C in Tokyo."[25] 77 years later, in 2018, Masumi Zaiki and Takehiko Mikami wrote on the basis of this and similar studies that "a clear urban heat island had already been observed in Tokyo before the Second World War."[26]

Put most simply, the Urban Heat Island (UHI) effect is the phenomenon whereby cities become hotter than their surrounding area. The effect is said to have been first observed by Luke Howard, who published his groundbreaking *The Climate of London* in 1833, in which he described an "excess of the temperature" in the urban environment. In that work, he ascribed this

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[24] See Hiroshi Shitara. "Fifty Years of Climatology in Japan." *Science Reports of Tohoku University*. Series 7, Geography (1978), 397-400; Yoshitaka Fukuoka. "Research in Climatology by Geographers in Japan." *Professional Geographer*, Vol. 32 No. 2 (1980). 225.

[25] Eichiro Fukui and N. Wada. "Horizontal Distribution of the Air Temperature in Greater Cities of Japan." *Geographical Review of Japan*, Vol. 17, Issue 5 (1941). 354-372. (Abstract in English).

[26] Masumi Zaiki and Takehiko Mikami. "Climate Variations in Tokyo since the Edo Period." *Tokyo as a Global City: New Geographical Perspectives*. Ed. Toshio Kikuchi and Toshihiko Sugai (Singapore: Singer, 2018). 45-51. For additional contextual discussion of the study that places it at the beginning of urban heat science in Japan, see Fumiake Fujibe. "Urban Warming in Japanese Cities and its Relation to Climate Change Monitoring." *International Journal of Climatology*, Vol. 31 Issue 2 (2011). 162-173; Jun Matsumoto et al. "Urban Climate in the Tokyo Metropolitan Area in Japan." *Journal of Environmental Sciences*, Vol. 59 (2017). 54-62.

effect to the verticality of urban development, which both blocked wind passages and trapped heat within tight geometric spaces, and the profusion of anthropogenic, or man-made, heat. After the 1940s, scientists intensively studied heat islands, and their various causes became better understood.[27] While I will be exploring in great detail the causes of urban heat as I progress, a few key elements should be understood from the start.

UHI are a result of the materials that cities are built out of (urban fabric), the geometry of the built environment (urban form), and the way people live within cities (anthropogenic heat). Materials like brick, concrete, and asphalt have various physical properties that trap heat within cities. Many urban materials have high *heat capacities* and dark surfaces, such that they can store large amounts of heat and reflect little radiation. Moreover, the ratio between heat capacity and heat conductivity in urban materials as opposed to wood or soil yields progressively higher *thermal diffusivity*, a measure of how deeply heat can penetrate a material. Likewise, urban materials have high rates of *thermal admittance*, which measures a material's ability to trap heat within it. The effects of these thermal properties are compounded by urban materials' moisture impermeability because the evaporation of water transmits energy away from earth and into the atmosphere. Water bodies can therefore have cooling effects, and highly permeable materials like soil or wood allow for greater evaporation. Vegetation too can produce a cooling effect as plants transpire water that then evaporates, or, more accurately, evapotranspirates. Urban materials like asphalt and concrete however are deliberately made to be durable and thus are highly impermeable.

[27] Gerald Mills. "Luke Howard, Tim Oke and the Study of Urban Climates." *Weather*, Vol. 63 No. 6 (2009). 153-157. See also Lisa Gartland. *Heat Islands: Understanding and Mitigating Heat in Urban Areas* (London: Earthscan, 2008). 1, 15.

In addition to these *intrinsic* properties, the interplay between these qualities and urban spatial organization is vital to the formation of heat islands. "Street canyons," formed through straight, often narrow roads lined with tall buildings trap heat. Likewise, limited "sky-view" from the ground then reduces the potential for heat to escape via the air. In addition to fabric and form, human activity, such as transportation or air conditioning, releases large amounts of heat into the air.[28] As I will describe in detail later, these factors must be understood not in isolation, but instead as highly interactive. In the simplest terms, heat islands are caused by the destruction of vegetation and water and their replacement by urban matter, which can have distinctly different thermal, moisture, and geometric properties.

In 1941, Fukui and Wada identified anthropogenic heat and the effect of wind patterns as the causative factors in Tokyo's heat distribution. After World War II, the controversies resulting from these conclusions laid the framework for urban climatology in Japan, and over the following decades, the causes of heating were further clarified in the terms explained above, with various scientists putting more or less weight on different factors. In the 21st century, Japanese scientists are at the forefront of urban climate research, and research on Tokyo has helped to clarify heat islands and their causes.[29] Over the last century, urban heat effects (as distinguished from global climatic changes generally) have heated Tokyo more than 2.0°C.[30]

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[28] For the most accessible but comprehensive introduction to heat island causation, see Gartland. *Heat Islands*, 1-25. For a more technical overview, see T.R. Oke et al. *Urban Climates* (Cambridge: Cambridge UP, 2017). 156-237. These two sources have been of the greatest use to me. For overviews that also give useful information on Tokyo specifically, see Troy Fowler. "Urban Heat Islands - Heating Up Japan." *HESO Magazine*. 1 July 2008. http://hesomagazine.com/environment/urban-heat-islands-the-other-type-of-island-in-the-japanese-archipelago/; Katsuhisa Uchiyama. "Cities and Heat Island." *Development Bank of Japan Research Center on Global Warming*. Discussion Paper Series No. 43 (2011). 8-9. Later citations in this introduction also usually include general descriptions of heat islands.

[29] Shitara. "Fifty Years of Climatology in Japan," 401-403; Hiroyuki Kusaka. "Recent Progress on Urban Climate Study in Japan." *Geographical Review of Japan*, Vol. 81 No. 5. (2008). 361-374, esp. 369.

[30] Junka Edahiro. "Efforts in Japan to Mitigate the Urban Heat Island Effect." *Japan for Sustainability*. Newsletter No. 73 (2008). https://www.japanfs.org/en/news/archives/news_id027856.html. The Inter-Ministry Coordination Committee to Mitigate Urban Heat Island reports that "the mean temperature in six large cities in Japan, including

UHI effects are not just insubstantial annoyances to urban residents' quality of life. As Lisa Gartland notes, "heat islands do not just cause a bit of additional, minor discomfort... [they] have serious effects on human mortality and disease."[31] As the global heat wave in the summer of 2018 reminded us, temperature change is a serious matter of public health. The heat wave's effect in Japan, where I was a student at the time, was well publicized, and one of my own professors missed class due to heat exhaustion in the unbearable weather. By August 7th, more than 70,000 people across the country had been hospitalized, and more than 100 had died from heat-related illness.[32] UHI effects can exacerbate heat waves, and as of July 25th, 71 Tokyoites had died from heat exposure.[33] Heat islands can also produce unexpected microclimatic effects, such as when localized "guerilla rainstorms" resulted in the death of five workers in Tokyo's sewers in 2008.[34]

In 2002, the Japanese government set up the Inter-Ministry Coordination Committee to Mitigate Urban Heat Island, which in 2004 produced an "Outline of the Policy Framework to Reduce Urban Heat Island Effects."[35] According to the Committee, the "urban heat island phenomenon is deeply embedded within urbanization which has been built up for a long period,

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Tokyo and Nagoya, risen 2-3℃ the globally averaged temperature risen 0.6℃. The trend of urban heat island phenomena in those large cities in Japan is significant even compared with the trend of the global climate change." "Outline of a Policy Framework to Reduce Urban Heat Island Effects." 2004. 2. Fujibe compares JMA data from Tokyo and 17 other weather stations used to monitor Japan's overall temperature change to conclude a difference of 2.8°C from 1901 to 2008 ("Urban Warming in Japanese Cities," 164).

[31] Gartland. *Heat Islands*, 2.

[32] Junko Ogura, Kaori Enjoji, and James Griffiths. "Japan: Heat Spikes to 41.1C near Tokyo as High Temps to Continue until August." *CNN*. 23 July 2018. https://www.cnn.com/2018/07/23/asia/japan-heatwave-deadly-intl/index.html; "Record 70,000 People Rushed to Hospitals since April 30 Amid Scorching Japan Heat Wave." *Japan Times*. 7 August 2018. https://www.japantimes.co.jp/news/2018/08/07/national/science-health/record-70000-people-rushed-hospitals-since-april-30-amid-scorching-japan-heat-wave/#.W5bxuOhKhaQ.

[33] "Protect the Socially Weak from Heat Waves." *Japan Times.* 25 July 2018. https://www.japantimes.co.jp/opinion/2018/07/25/editorials/protect-socially-weak-heat-waves/#.W5bwrOhKhaQ. For a recent study on the synergistic relationship between UHI and heat waves, see Lei Zhao et al. "Interactions between Urban Heat Islands and Heat Waves." *Environmental Research Letters*, Vol. 13 No. 3 (2018).

[34] "Guerilla Rainstorms Assault Tokyo." *Nippon*. 15 July 2014. https://www.nippon.com/en/features/h00064/.

[35] "Efforts in Japan to Mitigate Urban Heat Island Effect."

so it inevitably needs long term programs [for mitigation]" They specifically point to "anthropogenic heat emission... [and the] expansion of hard surface such as reduced green land and water and increase of buildings and road surface" and describe various policies and monitoring guidelines to combat their effects.[36] In line with this national recognition, the Tokyo Metropolitan Government produced a heat environment map designed to clarify target areas with pronounced heat island effects.[37]

Japanese policymakers are seeking to implement modern scientific and technological methods to "read" urban environments to provide valuable knowledge for future-oriented decision making. In essence, my goal here is to do just the opposite: using the results of scientific research on urban heat, I wish to read the history of Tokyo's urbanization *through* heat-inducing changes to the built environment. This science is absolutely vital to the history: without it, the causes of urban heat would be invisible within historical methodologies that use only contemporaneous written sources, if not invisible as a phenomenon at all. In declaring the "end of anthropocentrism," Timothy LeCain goes as far as to argue that historians might approach their work "as if there were no written record… analyzing the material environment of our subjects before subsequently turning to the documentary record."[38] Urban climatology is necessary to provide a map of the sorts of influences that are important to the genesis of heat islands, and combining history and science allows one to trace the development of these causative factors in a broader framework.

In doing so, I wish to provide a case-study that demonstrates a way that Japanese ability to take advantage of outer space resources, Japan's space power, declined with modernity as

[36] "Outline of a Policy Framework," 3-6.
[37] "Tokyo Uses Heat Map to Combat Heat Island Effect." *Japan for Sustainability*. 18 September 2005. https://www.japanfs.org/en/news/archives/news_id026058.html.
[38] LeCain. *The Matter of History*, 135-136.

humans in Tokyo found themselves progressively losing control over the powerful material forces around them. Because this story is intimately linked with the modern "rebuilding" of Tokyo in the late 19th century, I begin in Part 1 by exploring the global history of the built environment in the early modern period leading up to 1872. In this year, a fire destroyed the Ginza district in Tokyo, offering the newly formed government the chance to construct Ginza "Bricktown" as a symbol of Japan's modernity, a local manifestation of the modern urban fabrics and forms that were being diffused around the world.

Because a UHI effect was observed in Tokyo prior to World War II by a number of researchers, in Part 2 I trace the pre-war history of Tokyo's urbanization. I will describe here the historical development and science of factors associated with heating effects, focusing on the depletion of vegetation and the invention of modern river management.[39] Following this chronology, Part 3 focuses on the decades after World War II, when concrete accelerated the development of Tokyo's heat island and high-rise architecture led to new spatial configurations that produced a geometry of urban heat. By the end of the chapter, I hope to have demonstrated that the material and spatial configurations of modern cities (patterns which extend in significant ways beyond Earth) reflect the unpredictable entanglements of forces that interact in unintended and uncontrolled ways, a material history wherein human intentionality is ultimately peripheral to the key historical developments.

[39] Fujibe. "Urban Warming in Japanese Cities," 163; Shitara. "Fifty Years of Climatology in Japan," 224-225.

## Part 1 – The Durable Built Environment: 1666-1872

### The Great Rebuilding in World History

When the *Encyclopedia Britannica* entry on "Building Construction" includes the assertion that "the history of building is marked by a number of trends. One is the increasing durability of the materials used,"[40] it glides over a broad scholarly consensus on a key turning point in the history of architecture and urban planning that characterized the onset of modernity:

> Throughout most of human history, societies spent relatively little on buildings and fixed infrastructure. The dwellings where the population lived and carried on business were generally constructed over short periods of time out of inexpensive earthen or plant materials. Parts of these structures could be dismantled and carried to a new location if the community moved. Even those residing in more sedentary settlements exhibited little appetite for investing in more durable structures. In many places and over time, something changed, and people began to put additional resources into a varied group of buildings and infrastructure designed for longevity.[41]

Modernity might be thus characterized on a material level as the switch from one sort of built environment to a fundamentally different one that prized durability rather than flexibility. More broadly, the modern built environment, as it was erected in Tokyo in the late 19th century, was characterized by the attempt to insulate human activities from nature. People often uncritically buy into a certain folk ecology that imagines nature to be inherently patterned, balanced, static, and cyclical, while human time is linear and progressive.[42] The opposite is truer of the modern world: humans have *attempted* to create static, durable environments to insulate themselves from the chaos outside. Because its modern "rebuilding" was so revolutionary, because it prefigures the developments that took place in Ginza, and because its architects were

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[40] Alfred Swenson and Pao-Chi Chang. "Building Construction." *Encyclopedia Britannica*. Last revised 24 February 2017. https://www.britannica.com/technology/building-construction.

[41] Carole Shammas. "The Early Modern Built Environment Globally: The State of the Field." *Investing in the Early Modern Built Environment: Europeans, Asians, Settlers and Indigenous Societies*. Ed. Carole Shammas (Leiden: Brill, 2014). 1.

[42] Michael L. Cain et al. *Ecology.* 3rd Edition. (Sunderland: Sinauer Ass. Inc. Publishers, 2014). 9; William Cronon. "The Uses of Environmental History." *Environmental History Review,* Vol. 7 No. 3 (1993). 10-14.

so influential in modernizing Japanese architecture, the changes to Britain's built environment in the late 17th and 18th centuries is a useful preface to the history of Ginza Bricktown.

One of the defining moments of London's history, the Great Fire of 1666 destroyed 85% of the city, including more than 13,000 buildings, leaving tens of thousands homeless.[43] Both in England, and in Northern Europe more generally, the early modern period saw the replacement of largely wooden landscapes with more durable configurations of brick and stone. In Europe, and later in Tokyo, fire was essential to catalyzing these changes. As Carole Shammas puts it, "citizens in European towns, wealthier and more secular in their outlook, began to believe that they might be able to escape the destruction from conflagrations that regularly swept through their streets." Multi-story buildings, permanent materials, and wide, straightened, paved roads overtook "jumbled lanes" and "timbered dwellings." The so-called "rebuilding theory" of these developments was first applied to the English case, where the Great Fire stimulated a late 17th century turn towards a durable built environment that was "more durable and permanent by the eve of the industrial revolution."[44]

In Japan's contemporaneous "early modern" period, these shifts towards greater durability were not apparent; they would await the onset of Westernization and the globalization of the durable built environment in the late 19th century. Prior to these changes, Tokyo (then Edo) was an urban fabric built primarily of movable and transient timber structures. As Andre Sorensen puts it in his history of urbanization of Japan, "cities at the beginning of the Meiji period were densely built up and populated, constructed almost entirely of wood, with narrow

[43] Robert Tittler. "Review: Reconsidering the 'English Urban Renaissance': Cities, Culture, and Society after the Great Fire of London." *Journal of British Studies,* Vol. 40 No. 3 (July 2001). 420-421.
[44] Shammas. *Investing in the Early Modern Built Environment,* 8-11; Robin Pearson. "The Impact of Fire and Fire Insurance on Eighteenth-Century English Town Buildings and their Populations." *Investing in the Early Modern Built Environment.* 69-70.

unpaved streets and inadequate water supply and drainage," while Shammas points to a broader Asian phenomenon of "intentionally impermanent wooden dwellings that burned frequently and were rebuilt quickly."[45]

Drawing largely on secondary work, Sorensen sees this dense wooden landscape as one of the most important, and most problematic, legacies of the Tokugawa period with regard to city planning. "Fires large and small were a constant fact of life," he writes, pointing out that the Edo period saw a long and ineffective series of regulations to reduce fire. Surprisingly, merchants resisted these regulations "despite their obvious self-interest in fire prevention." Ultimately, Sorensen puts down the failure of Edo's fire regulation to the weakness of the central government's authority. In contrast, pointing to the aftermath of London's Great Fire, he argues that "European cities were built in stone and brick, not primarily as the result of a cultural preference for those materials, but because of strict enforcement of building regulations since the seventeenth century."[46]

Sorensen makes various ahistorical assumptions in reaching these conclusions, and Jordan Sand's understanding of Edo Japan as a very different kind of "fire regime" than the modern one is an important corrective to clarify the relationship between Edo's built environment and fire. Sand argues that Edo's fires are not best characterized as destructive, disruptive forces. In a much more important way, fire was merely a "consumer." While individuals certainly protected many of their valuable possessions and livelihoods, Edo's economy was driven by the rapid circulation, turnover and consumption of goods. Absent the recurring fires that swept through the city, surpluses of lumber and commodities would back up

[45] Andre Sorensen. *The Making of Urban Japan: Cities and Planning from Edo to the Twenty First Century* (London: Routledge, 2002). 60; Shammas. *Investing in the Early Modern Built Environment*, 20-21.
[46] Sorensen. *The Making of Urban Japan*, 41-43.

the flow of goods between the city and its environs. Fire was integrated into the metabolic flow of energy within the urban ecosystem. While Sorensen's argument universalizes a capitalistic economy, wherein individuals are driven to accumulate wealth, Sand shows that such an economic system simply did not exist during the Edo period, and "immovable property," in which value accumulated over time, was an invention that accompanied capitalistic modernization in Japan in the late 19th century. Prior to this shift, most buildings, if not lives and valuable possessions like fabrics and icons, were "intentionally impermanent," easily deconstructed, and portable. The "natural disaster" of fire became disastrous primarily because nature's unpredictability affronted the modern need for a static environment within which capital could be safely accumulated.[47]

By the late 19th century, an era characterized by global encounters, British observers of world cultures had gained a useful new metric through which to judge the degree of civilization of different nations: many Europeans "drew a strong connection between the rise of civilization and the construction of well-built permanent structures made of stone or brick."[48]As far back as the 1666 Act for Rebuilding the City of London, Charles II decreed:

> Brick is not only more comely and durable but also more safe against future perils of fire. Be it further enacted by and with the authority aforesaid that all the outsides of all buildings in and about the said city be henceforth made of brick or stone or of brick and stone together.[49]

Japan, with its profusion of impermanent wooden structures, was of course an easy target for Eurocentric lambasts. Even by the Meiji period, such understandings of the proper relationship

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[47] Jordan Sand. "Property in Two Fire Regimes: From Edo to Tokyo." *Investing in the Early Modern Built Environment*. 35-66.
[48] Shammas. *Investing in the Early Modern Built Environment*, 13.
[49] Charles II. "1666: An Act for Rebuilding the Citty of London." *British History Online*. Digitized from *Statues of the Realm: Volume 5, 1625-1680*. Ed. John Raithby (1819). https://www.british-history.ac.uk/statutes-realm/vol5/pp603-612#h3-0005. In the above excerpt, spellings have been modernized for readability.

between building material, beauty, and nature like these underscored the ways Europeans judged Japanese civilization and the way Meiji leaders decided to Westernize.

Though he argued against using architecture as a single metric by which to judge the level of civilization, Britain's first consul in Japan, Rutherford Alcock, upheld a larger discourse relating to the value of certain kinds of built environment. Alcock argued that Japan "has no architecture," pointing to the environmental conditions, primarily earthquakes and weak soil, which do not allow "a stable foundation… imposing a law of construction fatal to all architectural pretensions or excellence." "Nothing," he writes, "can be more mean or miserable looking than the streets of Edo."[50] Edo's buildings were weak and short-lasting, regularly consumed by earthquakes and fire. Comparing Alcock's remarks to Charles II's decree, one can see the longer cultural effects of the early modern rebuilding: stability, durability, and protection were preconditions for good construction now, and if Japan was to effectively modernize and become equal to the West, it too would have to adopt these new standards for its built environment.

**Ginza Bricktown**

In February of 1872, only a few years after the Meiji Restoration had displaced the Tokugawa shogunate, a large fire like many before broke out in the city and destroyed nearly all

[50] Rutherford Alcock. *The Capital of the Tycoon: A Narrative of a Three Years Residence in Japan, Vol. II* (London: Longman, Roberts, & Green 1863). 277-280. Some spellings have been modernized. Alcock disagrees with the argument that the "size and value of private dwellings and public buildings" by themselves can be used as a measure of civilization. However, in evaluating Japan's architecture as he does, the association between modernity and the durable built environment is still made. Moreover, he points to a broader disparagement of Japan's architecture that was also a heavy (if motivating) burden to Meiji leaders. See Anna Basham. "Changing Perceptions of Japanese Architecture, 1862-1919*." Britain & Japan: Biographical Portraits, Vol. VII*. Ed. Hugh Cortazzi. (Leiden: Brill, 2014). 487-500. For further discussion of this material basis for cultural superiority, see Gregory Clancey. *Earthquake Nation: The Cultural Politics of Japanese Seismicity, 1868-1930* (Berkeley: California UP, 2006). 14-19.

of the Ginza area, a small-scale merchant district of the now-renamed *Tokyo* ("Eastern Capital"). While not as destructive as the Great Fire of 1666 in London, the Ginza Fire destroyed about 3,000 buildings which had collectively housed 50,000 people across a 95-hectare region.[51] The re-timbering of this urban fabric which had been characteristic of Edo's ecology did not take place as it had in the past; Tokyo's fire regime had quite different motivations and existed in a quite different global context than Edo's.

For a variety of complex reasons, both internal and external to Japan, the Tokugawa Shogunate fell and was replaced in 1868 in what is referred to as the "Meiji Restoration," wherein sovereignty was nominally transferred away from the shogun and onto the Meiji emperor. The *Bakumatsu* era, commenced in 1853 with the aggressive arrival of Commodore Matthew C. Perry's "black ships" in Tokyo Bay, had been rife with anti-foreign sentiment. However, as the 1860s wore on, calls to "expel the foreigner" which had played no small part in catalyzing anti-Tokugawa feeling had transformed as the leaders in the western clans that would predominantly form the new Meiji government moved towards a position of assimilating Western knowledge and technology in order to stand as an equal "with the nations of the world."[52] In the famous Charter Oath of April 1868, the new state proclaimed that "knowledge shall be sought throughout the world so as to strengthen the foundations of imperial rule."[53] In

[51] See Sorensen. *The Making of Urban Japan*, 61; Neil Jackson. "Thomas James Waters (1842-98): Bibles and Bricks in Bakumatsu and Early-Meiji Japan." *Britain & Japan: Biographical Portraits, Vol. VII.* 479; Henry D. Smith. "Tokyo as an Idea: An Exploration of Japanese Urban Thought until 1945." *Journal of Japanese Studies*, Vol. 4 No. 1 (1978). 53;

[52] For a classic and riveting account of these events, see Marius Jansen. *The Making of Modern Japan* (Cambridge: Harvard UP, 2000). 257-414; For an older, but concise narrative, see Yoshio Sakata and John Whitney Hall. "The Motivation of Political Leadership in the Meiji Restoration." *Journal of Asian Studies*, Vol. 16 No. 1 (1956). 31-50. More recently, see Mark Ravina. *To Stand with the Nations of the World: Japan's Meiji Restoration in World History* (New York: Oxford UP, 2017).

[53] "The Charter Oath." *Source of Japanese Tradition Volume II: 1600-2000, Part Two, 1868-2000*. 2nd Edition. Ed. Wm. Theodore De Bary, Carol Gluck, and Arthur E. Tiedemann (New York: Columbia UP, 2006). 8.

the 1870s, Japanese leaders worked to bring Japan into the Eurocentric international order, a task that required a fundamental reshaping of every aspect of political, social, and material life.

In an 1875 manifesto, *An Outline of a Theory of Civilization*, Fukuzawa Yukichi, Meiji Japan's most prominent intellectual and forthright advocate of Western "civilization and enlightenment" derided the government's naïve and superficial obsession with installing Western material culture, rather than the more fundamental Western ideas, in the hopes of becoming "civilized": "I am always a bit upset at the way the Japanese government is building stone buildings and iron bridges… They are the most tangible of material things and the easiest of easy things to obtain."[54] However, at enormous expense, the new Japanese government did put great efforts into "rebuilding" Ginza along Western lines, "an attempt to reify in brick and stone the transition between Edo and Tokyo, Tokugawa and Meiji, premodern and modern Japan."[55]

These efforts had much more import than Fukuzawa imagined. In the international context of the early Meiji period, oligarchs like Saigo Takamori and Inoue Kaoru worked to present Japan as a Westernized nation to impress upon its Euro-American visitors its modernity. As we have seen, the connection between the durable built environment and civilization had already been forged by Europeans in the 19th century, and Meiji leaders worked within these values. Ginza was an especially opportune locale to "showcase" Japan's economic and aesthetic modernity because of its high visibility within Tokyo's transit system: "Ginza buildings and their arcades would demonstrate to the Western powers that Japan was on the road of capital

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[54] Yukichi Fukuzawa. *An Outline of a Theory of Civilization*. Trans. David A. Dilworth and G. Cameron Hurst III (Tokyo: Keio UP, 2008). 21

[55] Tristan R. Grunow. "Ginza Bricktown and the Myth of Meiji Modernization." *Meiji at 150: Visual Essays*. The University of British Columbia. https://meijiat150dtr.arts.ubc.ca/essays/grunow/; Roman Cybriwsky. "From Castle Town to Manhattan Town with Suburbs: A Geographical Account of Tokyo's Changing Landmarks and Symbolic Landscapes." *The Japanese City*. Ed. P.P. Karan and Kristen Stapleton (Lexington: Kentucky UP, 1997). 61-62.

accumulation. Brick announced that the capital would have fixed capital."[56] More fundamentally, Japan:

> witnessed the construction of a new state, a new society and a new built environment to express its identity and ambitions… Architecture was charged with a mission of the highest national significance: proclaiming loudly on every city block and street corner Japan's assurance and authority as a modern state.[57]

The 1872 Fire offered up to Meiji leaders what seemed like a *tabula rasa*, unburdened by history: ripe terrain for a demonstration of Japan's acceptance of a new kind of built environment and way of life. Inoue, who led the construction of the so-called Ginza Bricktown, referred to it as a "shortcut to civilization and enlightenment," a phrase that no doubt would have provoked the Fukuzawa's ire.[58]

In its drive to modernize Tokyo's built environment, "no matter how much money it costs," as Saigo stated, the Meiji government would recruit the aid and expertise of Western, largely British, engineers and architects.[59] In the 1870s, Meiji leaders began hiring these experts in their ministries and new colleges. Josiah Conder, who arrived in 1877, is often termed the "father of modern Japanese architecture" for the great influence he had on the first generation of Meiji architects.[60] However, even prior to Meiji Japan's recruitment efforts, other British agents and so-called "adventure-engineers" had begun to find their niche in Bakumatsu Japan. British agents like Thomas Blake Glover played substantial roles in providing funding and technology

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[56] Sand. *Investing in the Early Modern Built Environment*, 61; Sorensen. *The Making of Urban Japan*, 61; Smith. "Tokyo as an Idea," 53-54.
[57] William H. Coaldrake. *Architecture and Authority in Japan* (London: Routledge, 2002). 208-209.
[58] Grunow. "Ginza Bricktown and the Myth of Meiji Modernization."
[59] Clancey. *Earthquake Nation*, 11-28. Quoted is Saigo Takamori (p. 12) with reference to Ginza. See also Olive Checkland. *Britain's Encounter with Meiji Japan: 1868-1912* (London: Macmillan, 1989). 42-56; Michael Auslin. "Japan's Modern History: A Very British Affair." *Times Literary Supplement*. 12 January 2018. https://www.the-tls.co.uk/articles/public/meiji-restoration-anniversary/.
[60] Clancey. *Earthquake Nation*, 13; Jackson. *Britain & Japan: Biographical Portraits,* 469-470.

for the western domains, like Satsuma and Choshu, which were fundamental to the Restoration and would remain the key players in the new state.[61]

It was through Glover that Thomas Waters came to work in Japan, being hired as the Chief Engineer for Satsuma, where he worked to build sugar and cotton mills. After 1868, Glover's allegiances to Satsuma transferred to the new state, and Waters was hired again to complete the new Mint at Osaka, which itself was initially run by a different Western advisor. In completing the Mint, Waters largely used brick, a novel building material in Japan which had only been used before in some western domains in the 1850s. By 1870, Waters had moved to Tokyo and was appointed Surveyor General of the Meiji state.[62]

It was in this position that Waters would oversee the reconstruction of the Ginza district as a modern "bricktown." Using this revolutionary material, Ginza's roads would be paved, widened, and straightened in a gridded pattern so as to reduce the risks of fire. Flanking these wide avenues were largely multi-story brick buildings with a British, Georgian-style décor, striking a similar tone to London's Regent Street. As in 1666, landowners were required to build in brick or stone, although these regulations were of course bent in less prominent street-sides, and land-owners often resisted heavy-handed impositions.[63] With brick paving, multi-story buildings, and straight gridded roads, Tokyo was being rebuilt as a modern, durable city, resistant to the fiery fluctuations of the natural world. Western visitors like Isabella Bird certainly took note of these developments. In an oft-alluded-to account, Bird describes the

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[61] Jackson. *Britain & Japan: Biographical Portraits,* 470. For more on Glover, see Alexander McKay. *Scottish Samurai: Thomas Blake Glover, 1838-1911* (Edinburgh: Canongate, 1997).

[62] For this general narrative of Waters' time in Japan, see Jackson as well as Meg Vivers. "The Role of British Agents and Engineers in the Early Westernization of Japan with a Focus on the Robinson and Waters Brothers." *International Journal for the History of Engineering and Technology,* Vol. 85 Issue 1 (2015). 115-139. For the most detailed treatment of Waters, see Meg Vivers. *An Irish Engineer: The Extraordinary Achievements of Thomas J. Waters and Family in Early Meiji Japan and Beyond* (Brisbane: Copyright Publishing, 2013).

[63] Jackson. *Britain & Japan: Biographical Portraits,* 479-480; Sorensen. *The Making of Urban Japan*, 61-62; Grunow, "Ginza Bricktown and the Myth of Meiji Modernization."

modern "vulgarized" Tokyo as "more like the outskirts of Chicago or Melbourne than an Oriental City."[64] However, what many who cite this quote miss is that here she is describing the various smaller wooden buildings, built in a "debased Europeanized or Americanized style." The larger stone and brick buildings she judges to be "really handsome and solid."[65] Like Alcock earlier, along with many other observers, she links the durability of the built environment with aesthetic value.

Japanese observers also took note of the radical departure that Bricktown represented. Woodblock prints of Ginza proliferated, highlighting (and distorting) the modernity and liveliness of the district. In *New Tales of Tokyo Prosperity*, Hattori Basho waxes poetic: "Tall two-story buildings tower into the blue sky one after the other as high as mountains… with a grandeur such that it completely imitates Western buildings!... The stone buildings, in other words, are like those of London, the English capital."[66] According to Ai Maeda, Basho's account of Ginza provocatively centers on *things* themselves, the material civilization that was being transposed:

> with row after row of the same standardized building design along the eight blocks of the Ginza. Constructed in the functional materials of white plaster over brick… den[ying] the possibility of going beyond the immediate perception of the material object itself… a symbol of 'civilization and enlightenment' that is merely a myth emptied of meaning… [its] buildings serving as halls for the worship of fetishized commodities.[67]

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[64] For example, her account is cited in both Sorensen (*The Making of Urban Japan*, 62) and Jackson (*Britain & Japan: Biographical Portraits*, 470). Jackson cites Sorensen as his source, and Sorensen cites Edward Seidensticker, with whom the popularity of the anecdote possibly originates. Sorensen cites his 1991 *Tokyo Rising*, but once can find the quote more recently in Edward Seidensticker. *Tokyo: From Edo to Showa, 1867-1989. Two Volumes in One: Low City, High City and Tokyo Rising* (Singapore: Tuttle, 2010). 74. For the original, see Isabella Bird. *Unbeaten Tracks in Japan: Unbeaten Tracks in Japan, Volume 1: An Account of Travels in the Interior, Including Visits to the Aborigines of Yezo and the Shrines of Nikko and Ise* (London: John Murray, 1880). 34

[65] Bird. *Unbeaten Tracks in Japan*, 34.

[66] Quoted in Grunow. "Ginza Bricktown and the Myth of Meiji Modernization."

[67] Ai Maeda. "The Panorama of Enlightenment." Trans. Henry D. Smith II. *Text and the City: Essays on Japanese Modernity*. Ed. James A. Fujii (Durham: Duke UP, 2004). 81-82.

**What a Brick Wants**

As Timothy LeCain dramatically writes in introducing his neo-materialist synthesis, "the time has come to talk of *things* (italics mine)."[68] Specifically, the time has come to talk about brick and how this seemingly simple material was interwoven so intrinsically into Japan's experience of modernity. So far, I have been discussing modernity as if it itself, as an abstract concept, is at the center of this history. However, "more often than not, it is not so much the case that abstract human minds interact with abstract sociocultural phenomena but rather that embodied human beings interact with material organisms."[69] In a very literal way, brick helped to *shape* Japan's modernization and even *was* Japan's modernization. As William Coaldrake writes, "brick assumed iconic significance as a physical embodiment of things Western and modern, of the civilization and enlightenment extolled by the Japanese political and intellectual leaders."[70]

Returning to the European context, "British architecture and civil engineering were synonymous with brick and stone… Masonry was the very identity of both professions."[71] As London was rebuilt, there emerged a "new vernacular based upon the use of fired earth," as southeast England was lacking in stone, which was prohibitively expensive, and in the 18th century, "London became a city of brick."[72] Whether in London or Tokyo, it was largely brick's fireproof durability that prompted the "brickification" of the 19th century urban fabric.[73] James Ayres' history of Georgian architecture points to the ways that the built environment of English

[68] LeCain. *The Matter of History*, 73.
[69] Ibid, 14.
[70] Coaldrake. *Architecture and Authority in Japan*, 236.
[71] Clancey. *Earthquake Nation*, 14.
[72] James Ayres. *Building the Georgian City* (New Haven: Yale UP, 1998). 101; James W.P Campbell and Will Pryce. *Brick: A World History* (London: Thames & Hudson, 2003). 160.
[73] See Coaldrake. *Architecture and Authority in Japan,* 236.

cities was a function as much of the embodied experiences of craftsmen themselves, who engaged daily and intimately with materials like brick, as it was of the abstract drawings of city planners and architects.[74]

Just as in England, brick was a good material of choice for modernization because of its easy procurement, its durability, its relative ease of manufacture, and the speed with which brick forms can be erected.[75] While the technology and skills related to brickmaking and bricklaying were "transferred" from Britain to Japan, bricks were not "merely passive raw materials which humans bend to their will."[76] To emphasize this truth, the architect Louis Kahn once described an imaginary conversation with a brick: after asking the brick what it "wants," Brick replies "I like an arch," despite the expenses the architect complains about. Continuing on, Kahn remarks, "It's important, you see, that you honor the material that you use… You can only do it if you honor the brick and glorify the brick instead of shortchanging it."[77] The lesson here is that the material fabric of the world is not endlessly shapeable by human hands. When humans do shape the things around them, it requires a deep engagement with the material properties, potentials, and limitations those things have. Additionally, these things present real constraints on how they can be shaped.

In the late 19th century, Thomas Waters worked to elevate the status of bricks in Japan. The Mint at Osaka, mentioned earlier, also required the transmission of knowledge of brick construction. As one letter from Waters' sister notes, "he has to begin at his old work showing

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[74] Ayres. *Building the Georgian City*, 1-7.
[75] Coaldrake. *Architecture and Authority in Japan,* 236-238.
[76] LeCain. *The Matter of History*, 15.
[77] "Brick." William Hall. *Brick*. Ed. William Hall (New York: Phaidon, 2015). 7. See Nathaniel Khan and Susan Rose Behr. *My Architect: A Son's Journey*. Directed by Nathaniel Kahn (Louis Kahn Project Inc., 2003). I was introduced to this fuller quote in the documentary in Costas Voyatzis. "'Even A Brick Wants To Be Something' - Louis Kahn." *Yatzer*. 9 June 2013. https://www.yatzer.com/even-brick-wants-be-something-louis-kahn.

them how to make bricks before they can fairly commence!"[78] Bricktown naturally required an even larger effort on the part of Waters and the Japanese he worked with. Patented only in 1858, the Hoffmann kiln allowed for the continuous firing of bricks, creating the possibility for much more efficient mass production. It was three large Hoffmann kilns, constructed just outside of Tokyo, which allowed for the reconstruction of Ginza. Indeed, these kilns *needed* to mass-produce to be economical at all; the proliferation of bricks in Tokyo was thus almost inevitable once the construction of Hoffman kilns, both under Waters and after, entrenched Japanese city planners and construction managers into a feedback cycle based on the material forces the kilns created and the capitalist economy that had supplanted Edo's *ecology-economy* of turnover.[79] In other words, the value of bricks as a commodity meant that every brick needed to be used and sustained at its fullest economic potential, eliminating waste.

In Neil Jackson's words, the choice of Waters, "the builder of brick kilns," was likewise "almost inevitable" given his experience with the material.[80] In some of Waters' instructions on the use of brick in Ginza, one gets a much stronger sense of the intimate physical knowledge and material engagement that was required as a precondition for Bricktown:

> 2. Mortar, for brickwork, is of the greatest importance. It is made of one part by measure of fresh stone lime & three parts of sharp river sand. The lime is measured before it is wet, as it increases much in volume when slaked & so does not give the correct proportion.
> 3. The sand & lime must be thoroughly well mixed and used immediately.
> 4. If the lime does not become hot when wet it must be rejected.[81]

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[78] Vivers. *An Irish Engineer*, 88.
[79] For Hoffman kilns generally, see Campbell and Pryce (*Brick: A World History*, 212). For the role of the kilns in Ginza, see Vivers, "The Role of British Agents and Engineers," 130-131. For more details regarding brick architecture in Meiji Japan outside of Ginza, see Coaldrake. *Architecture and Authority in Japan*, 236-238. For more on the misplaced categorical divide become "economy" and "ecology," see Walker. *The Lost Wolves of Japan*, 176-183.
[80] Jackson. *Britain & Japan: Biographical Portraits*, 479.
[81] Vivers. *An Irish Engineer*, 110-113.

Even these very brief notes reveal much about this history: the making of Bricktown, and by extension the modern urban fabric that would generate urban heat as it developed in the 20th century, required an intimate knowledge of the constraints and potentials of the materials involved. Those who worked with these materials understood that the history of the built environment is not just a history of how humans have changed their world, but how humans have adapted to and worked with the powerful and complex matter around them to suit both their needs and the needs of the objects they partner with.

However, the instructions given by Waters naturally are about the knowledge *he did* have concerning the manipulability of bricks and mortar, but bricks have other by-products that were not as well appreciated. Bricks have high heat retention and relatively high thermal admittance. Additionally, bricks are much less permeable to water than materials like soil or vegetation are, a property builders' desire as this quality increases durability.[82] As Waters writes, "bricks when well burnt resist frost & fire and if properly laid in good mortar, form a strong and very durable house."[83] The durable and modern built environment, however, would come at a cost: the gradual heating of the cityscape.

Photographs from the time period reveal urban characteristics which signal the development of Tokyo's urban heat (Fig. 1.1-1.3). The thermal and moisture properties of brick, which line the buildings and road surfaces, trap heat which is then released gradually at night. Likewise, the straight, gridded roads and multi-story buildings suggest the later development of street canyons, whose spatial properties also serve to trap heat. The photos reveal a sparsity of

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[82] See Gartland. *Heat Islands*, 19; Dan Cruickshank. "The First Cities." *Brick*. 9; Oke et al. *Urban Climates*, 168-171; Rebecca Pineo and Susan Barton. "Permeable vs. Impermeable Surfaces." *Sustainable Landscape Series*, Bulletin #125. University of Delaware Botanic Gardens. 31 January 2009. https://cdn.canr.udel.edu/wp-content/uploads/sites/16/2018/03/12024201/Permeable_Impermeable_Surfaces.pdf.

[83] Vivers. *An Irish Engineer*, 110.

vegetation and open soil, porous materials through which water can flow and evaporate, leaching heat away with it. As Bricktown evolved, many trees in Ginza, sources of evapotranspiration and shade, also disappeared, becoming "victims of urbanization."[84]

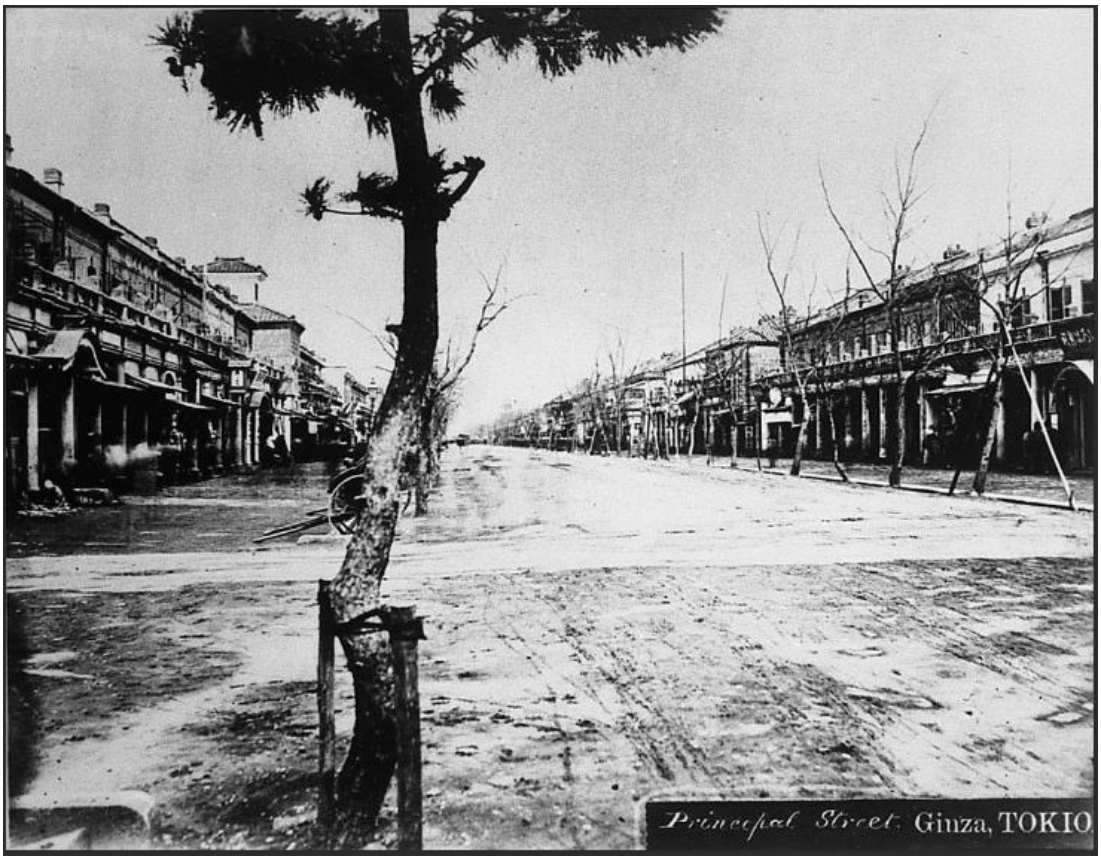


Figure 1.1

[84] Seidensticker. *Tokyo: From Edo to Showa*, 76.

Figure 1.2


Figure 1.3[85]

[85] "Photographs of Architecture in Meiji and Taisho Periods." *Architectural Institute of Japan Library Digital Archives*. 建築學會 & 明治建築資料に関する委員会 編. *明治大正建築写真聚覧*. Originally published in 1936. Last Updated 25 February 2008. https://www.aij.or.jp/da1/zumenshasin/meijitaishou.html.

The modern built environment, as prefigured in Ginza Bricktown, already evinced several characteristics and trends which would become endemic to urban heat islands: impermeable materials with retentive thermal properties; the loss of vegetation and natural land-cover; straight, paved roads flanked by buildings of increasing height. Regardless of what properties Waters and Japanese planners could manipulate and control to create Bricktown, the interactions between modern built environments and solar energy that followed in Bricktown's wake were unpredictable and unintended. Thus far, I have focused on the interactions between humans and materials, but what urban heat shows is that the interactions between non-human material forces are just as historically significant. Making history more materialistic does not entail determinism, at least in any methodologically important way, but can lay bare the delicate contingencies involved when material forces are pushed against one another.[86] Matter, to put it bluntly, matters, not merely in the way humans engage with it, but in the ways things themselves interact to produce surprising landscapes, ones that certainly are not entirely under human control and may not be altogether inviting to human occupation.

Historians are rightfully dubious about stories of modernity and westernization that assume that "receptive" societies passively take on western knowledge and technology. More broadly, scholars have criticized narratives that speak of abrupt shifts in the historical record, as if 'we moderns' escaped from history and forged our societies and institutions with no constraints. The historiography of Ginza Bricktown, and the modern "rebuilding" more broadly,

[86] Deeper metaphysical questions about determinism are not of great interest to me here. The point is that at a large enough scale, the relationships between material objects and natural forces are indeterminate and contingent. Perhaps at a much smaller scale, determinism is true, but at the level we do history, this possible determinism is not a useful hypothesis. In other words, even if determinism is true, this is not *methodologically* important for environmental historians.

is full of these narratives.[87] Tristan Grunow does much work to deconstruct these myths, arguing that Bricktown did not develop nearly so neatly, and the passing years saw much traditional construction and rule-breaking. The redevelopment itself was hotly contested among residents and planners, and is not anything like a "success story" for Japanese westernization. After all, none of Bricktown exists today.[88] Gregory Clancey has powerfully argued that Western architectural methods were not simply replicated in Japan, but were only partially reconstructed, and distinctly altered, in culturally-situated ways.[89]

These qualifications, and outright denials, of the standard Eurocentric narrative of modernity are necessary and of great value. However, it is not enough to point to the ways cultural difference constrains and shapes the ways "modernity" was received by the "non-western" world; in fact, such a preoccupation with abstracted "cultures" creates a very different kind of myth whereby material changes matter little in the face of cultural asymmetries. Another way of upending Eurocentric "diffusion" narratives is to point instead to how matter itself constrained and enabled the ways societies could act, not in vulgarly deterministic ways, but in more complex, contingent ones. The development of a new urban fabric in Europe was in many ways a condition of the materials themselves, materials like brick which, according to Louis Kahn, have their own aims and purposes to which builders have to adapt. In contrast to those convergence histories that seek to blur the modern divide in Japanese environmental history, Brett Walker writes, in regard to emergent attitudes towards wolves in this same period, that

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[87] For a broad critique of rebuilding narratives in Britain, see Pearson. *Investing in the Early Modern Built Environment*, 67-94.

[88] Grunow. "Ginza Bricktown and the Myth of Meiji Modernization." Seidensticker also points to the more complex history of Bricktown (*Tokyo: From Edo to Showa*, 72-77). Grunow explores local resistance to Ginza reconstruction measures, and how it shaped Japanese urban planning policy during the rest of the Meiji period, in his dissertation. "Empire by Design: Railways, Architecture, and Urban Planning." PhD Diss. University of Oregon (2014). 21-108.

[89] For an overview, see Clancey. *Earthquake Nation*, 1-10. Sorensen also puts great emphasis throughout *The Making of Urban Japan* on the distinct ways Japanese cities developed and the complex heritage of Tokugawa-era developments.

"with striking ease, Meiji officials brushed aside centuries of reverence for and fear of wolves – and, to a lesser degree, the entire East Asian order that supported such traditions – replacing them, brick by brick with the edifice of the modern order."[90] In Ginza, those bricks were not as metaphorical.

As Japan found itself encountering these very different material systems in the late 19th century, they were not encountering the empty symbols of European civilizations, but very real and powerful forces that had their own gravitational pull. The power of hard and durable building materials served as the condition of possibility for capitalist modernity. Fukuzawa, in distinguishing so sharply between the "easy" material culture of Westernization and the more "essential" abstract qualities of it, naïvely imagined that these two things, matter and culture, are not inextricably intertwined.

No absolute scientific evidence may exist on the thermal characteristics of Bricktown itself, but what is clear is that Bricktown signaled a new kind of city, the kind that would trap heat within its geometry and materials. One may not be able to reduce Bricktown to a completely "new" kind of urban space, imported directly from the West, but neither should one gloss over the very different kinds of physical relationships that the developments in Ginza announced, uncontrolled developments that would over the course of the 20th century make Tokyo into an oven.

[90] Walker. *The Lost Wolves of Japan*, 133.

## Part 2 –Modernizing Tokyo's Land Use before World War II

### Modernity in Japan's Environmental History

In "Modernity, Water, and the Environment in Japan," Gavin McCormack paints a romanticized picture of Edo/Tokyo's evolving river regime, one that shifts in the late 19th century from being "organic, symbiotic, and adaptive" to "divisive, dominating, and controlling." Beginning his essay, McCormack describes premodern Japanese relationships with nature as harmonious and idyllic, "an eco-society without peer," prior to the fall from grace as "Japan chose to adopt not only Western science and technology but Western views of nature and practices of environmental engineering." Like many other aspects of its environment, modern Japan completely changed course in its relationship to water as it began to engineer rivers to marginalize them from urban life and reduce their functions to utilitarian economic goals.[91]

For decades now, this sort of declensionist story has been attacked for misrepresenting Japan's environmental record and orientalizing Japanese thought. In a classic 1991 article, Tessa-Morris Suzuki takes these myths as a foil against which she stakes out an intellectual history of Tokugawa Japan wherein ideas about nature were not homogenous, but trended towards viewing nature as a *resource* with a value defined merely in terms of its instrumental usefulness.[92] More recently, Federico Marcon and others have argued for a convergence between Japanese and European thought and science in the 18th and 19th centuries, pointing to independently evolving understandings of nature in Japan as a something that could be given instrumental value, commodified, and integrated into the political economy.[93]

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[91] Gavin McCormack. "Modernity, Water, and the Environment in Japan." *A Companion to Japanese History*. Ed. William M. Tsutsui (Malden: Blackwell, 2007). 443-459.
[92] Suzuki. "Concepts of Nature and Technology in Pre-Industrial Japan." See more recently Paul Waley "The Urbanization of the Japanese Landscape." *Routledge Handbook of Japanese Culture and Society*. Ed. Victoria & Theodore C. Bestor and Akiko Yamagata (London: Routledge, 2011). 89.
[93] See footnote 15

In more material approaches, historians have also worked to critique these myths as well. In two essays from the recent benchmark collection *Japan at Nature's Edge: The Environmental Context of a Global Power*, Phillip C. Brown and David Howell both push back against these reductionist portraits of Japan's harmonious relationship with nature. Brown points to the longer history of a "controlling urge" in Japan's history of river engineering, while Howell looks to the history of Edo's sanitation practices, concluding that they did not spring from what we today would consider "environmentalist" intentions and were inconsistent with the an ahistorical "Eco Edo" imaginary.[94] This point about intentions and worldviews resonates in Conrad Totman's prescient 1989 study on premodern forestry in Japan. Totman argues that practical concerns with rampant deforestation drove Japanese timber policies far more than any primordial ethical-religious Shinto or Buddhist precepts.[95]

The relationship between rivers and cities in Edo and Tokyo has offered ample ground for historians to further challenge these orientalist myths. On the one hand, many have pointed to the ways Edo planners deliberately engineered the landscape to avoid risk and promote commerce: "Japan's vigorous economic growth in the Edo period was based on an equally vigorous exploitation of natural resources... rivers were dammed, dredged, and diverted to meet the economic and social needs of a rapidly growing society."[96] In addition to exploring Edo's river regime in great detail, Roderick Ike Wilson discredits this mythology from the opposite end, seeing a false dichotomy in the standard narrative that Tokyo emerged as a modern city by revolutionizing its transportation system from one that relied on rivers to one that relied on roads

[94] Philip C. Brown "Constructing Nature." *Japan at Nature's Edge,* 90-114; David Howell. "Fecal Matters: Prolegomenon to a History of Shit in Japan." 137-151.
[95] Totman. T*he Green Archipelago*.
[96] Patricia Sippel. "Japan's First Urban Water Disaster: The Great Kanto Flood of 1742." *現代史研究 / 東洋英和女学院大学現代史研究所 編,* No. 10 (2014). 1-34.

and rails. For Wilson, Tokyo's modernization actually increased the reliance on Edo's complex river system in line with its industrialization.[97]

That "water versus wheels" paradigm points to the broader myth as it is meant to evoke a nostalgia for the "change from a water-based urban culture and economy to a land-based one, and from one fashioned out of wood to one built of steel, from the fluid spontaneous rhythms of flowing water to the solid, angular patterns of functional planning."[98] If environmental historians working on Japan are increasingly challenging a narrative that sets premodern and modern Japanese ideologies and environmental ideologies against one another, in what way are the two related? Marcon suggests that anti-modern Japanese thinkers produced a discourse concerning Japanese pre-modernity to provide a foil for the modernity they rejected.[99] In another vein, Robert Stolz offers that "Meiji 'civilization and enlightenment' was less a clean break with an imagined premodern harmony between Japanese society and nature than the apotheosis of all these previous, partial reifications of humans and nature."[100] In other words, modernity cohered various strands of premodern anthropocentrism.

As with the recent historiography of Bricktown which has challenged standard narratives of one-way "transfer," these solutions seem unsatisfactory in the way they explain Japan's experience of modernity. Rather, I believe that McCormack's heavy-handed point, that there is a sharp distinction between the way Japanese leaders interacted with nature before and after the Meiji Restoration, is in need of some salvaging. As with Bricktown, it is important to take

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[97] Roderick Ike Wilson. "The Engineering of Japan's Modern River Regime, 1600-1920." PhD Diss. Stanford University (2011).
[98] Paul Waley. "By Ferry to Factory Crossing Tokyo's Great River into a New World." *Japanese Capitals in Historical Perspective: Place, Power, and Memory in Kyoto, Edo, and Tokyo*. Ed. Nicholas Fieve and Paul Waley (London: Routledge, 2002).
[99] Marcon. *The Knowledge of Nature and the Nature of Knowledge*, 299-306.
[100] Stolz. *Bad Water,* 25.

account of the important material convergences that did in fact push Tokyo since the late 19th century toward microclimatic tendencies in line with cities around the world. In the previous section, I argued that Bricktown prefigured a kind of built environment that had key differences from the kinds of urban fabrics that had existed in Edo. These material and spatial differences can be read as conducive in various ways to heating. Urban heat islands are also the result of the removal of rivers and vegetation from the urban landscape.

**Tokyo's Water in Meiji Japan**

The traditional narrative concerning Japan's modern river regime relies on a distinction between "high" and "low" water policies. Low-water regimes integrate social and riparian systems, using rivers as essential means of transport and commerce. Moreover, rivers are integrated into daily social life. In contrast, high-water policies reduce rivers largely to environmental hazards, sources of unpredictable flooding that technological fixes can mitigate. The Meiji government reframed the relationship between people, society, and water, "modernizing" it so as to insulate productive forces from environmental fluctuations.[101] These developments parallel the shift to a modern fire regime discussed above.

In his dissertation and later work, Roderick Wilson pushes against this grand narrative, seeking to differentiate the way Japan's water regime developed in rural and urban areas at the turn of the century. To be sure, in rural areas and around cities, there was a sharp modern shift whereby the Meiji government enacted a high-water regime, led specifically by the Home Ministry. However, within Tokyo, rivers were sustained and integrated into the city's economic metabolism as a transportation network. The use of and demand for navigable rivers actually

[101] McCormack. *A Companion to Japanese History*, 445-449; Wilson. "The Engineering of Japan's Modern River Regime," 10-17.

increased in the late 19th century, not in conflict with the development of railways and roads, but in support of them. "Water and wheels" developed in tandem and the development of the two were positively correlated.[102]

A 1908 map of the Tokyo area demonstrates this mutualistic relationship starkly (Fig. 1.4). In addition to pointing to urban sightseeing spots and important locations, the map also superimposes urban rivers and recently constructed railways and tramways. One can immediately visualize the relationship between them as the rails and trams follow along the edges of the rivers as a tight symbiosis.[103] As modern industry and transportation developed, rivers served to supply factories and stations with cargo and distribute goods around the city. The rivers thus served commerce, albeit in the context of modern industrialization, as much as they had in the "low-water" era, or, as Fransje Hooimeijer puts it, "water continued to exert considerable power over the urban environment."[104]

[102] Wilson. "The Engineering of Japan's Modern River Regime," 133-188.
[103] For a distinctive cultural history of Japan's modernizing transportation networks, see Alisa Freedman. *Tokyo in Transit: Japanese Culture on the Rails and Road* (Stanford: Stanford UP, 2011).
[104] Fransje Hooimeijer. "History of Urban Water in Japan." *Urban Water in Japan*. Ed. Fransje Hooimeijer and Rutger de Graaf (London: CRC Press, 2008). 43. For a collection of Western case studies that similarly point to the way modernity transformed river regimes, see Stephane Castonguay and Matthew Evenden (ed.). *Urban Rivers: Remaking Rivers, Cities, and Space in Europe and North America* (Pittsburg, Pittsburg UP, 2012).

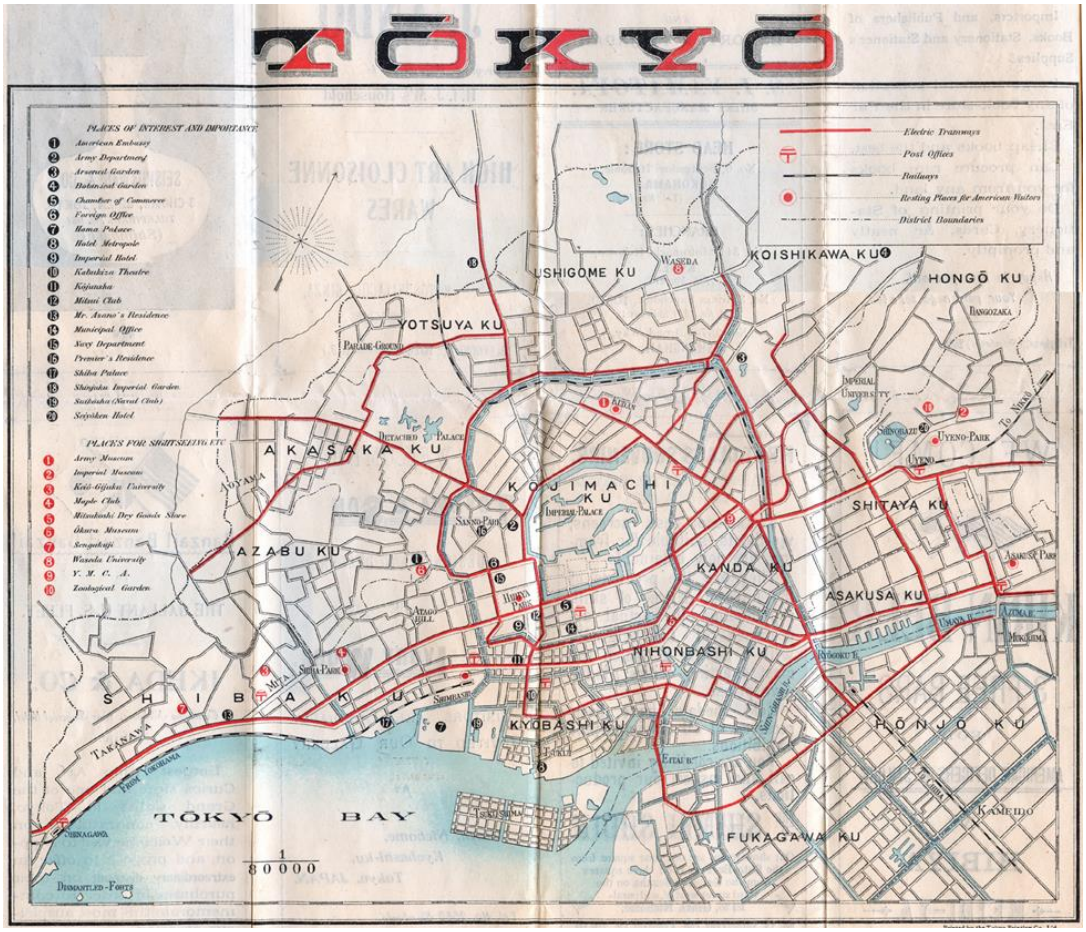

Figure 1.4[105]

However, Wilson points out that river integration systems were not holdovers from the Edo era, but were reimagined, and indeed reengineered, to serve the modern needs of industrial capitalism. In another author's words, "heavy industrial transport became the main use of the waterways. Prevent[ing] development of... a diversity of use along the river shores."[106] While Wilson stresses the continuity of a water-based economy, his argument also points to the how rivers were in fact used in very different ways. His argument does not as much undermine the notion of modernity as a rupture in historical time as it does re-evaluate the nature of this shift.

[105] "Tokyo, 1908." Tokyo: 1900-1950. Cartography. *Old Tokyo: Vintage Japanese Postcard Museum, 1900-1960.* Last updated 2018. http://www.oldtokyo.com/cartography/.

[106] Gloria Asami Lili and Asako Berwert. "Tokyo River Fragments: An Urban Analysis of the Role of the Water Network in the Structure of Tokyo Metropolis." Master Thesis. Ecole Polytechnique Federale de Lausanne (2010). 109.

Most importantly, Wilson argues along with McCormack and others that the functionality of rivers was reduced under modern capitalism as they were subsumed under industrialism and their cultural and recreational values were erased over time. In the Meiji era, rivers' function as cheap and ready-made transportation infrastructure served modernization, but Wilson notes that these same motivations would, in the post-war period, work to bury rivers under concrete.[107]

Wilson's work indicates that modernity must be defined more carefully. Bricktown, as I argued, should not be understood as the starting point of a new kind of urban fabric that immediately overcame Tokyo's wooden forms over time; at least until 1945, Tokyo's urban mass was largely timber. Likewise, rivers did not suddenly disappear from the cityscape. In fact, by superimposing two maps from 1858 and 1896; one can note a near one-to-one correspondence between river routes across the city (Fig. 1.5-1.6). However, just as Bricktown established a prototypical forerunner of the kind of urban fabric and form that modernity announced, the *social* geography of Tokyo's rivers was changing quickly just beneath what appears in these maps to be a more stable physical environment, even as they were being more subtly reengineered to be more productive.

[107] Wilson. "The Engineering of Japan's Modern River Regime," 135-136.

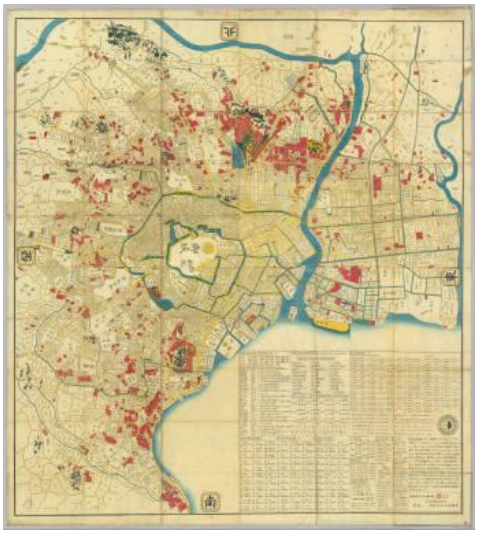

Figure 1.5

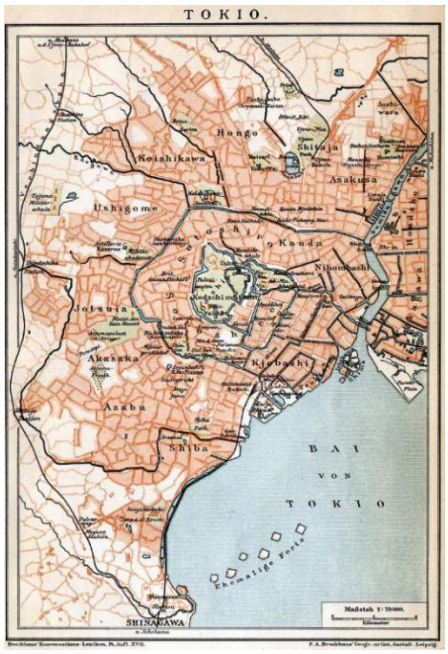


Figure 1.6[108]

The Sumida River, on the eastern periphery of Tokyo, served a variety of cultural roles during the Edo Period, as a site of recreation, entertainment, and sanctity as well as commerce and work. In the late 19th century, the Sumida became merely an "industrial artery," first to service kilns like those discussed earlier along with glassworks, later largely textile mills.[109] As summarized by Paul Waley:

> the ideological changes that transformed Tokyo evolved naturally over several decades. They were the spatial manifestations of social change, and they took time to make themselves apparent. The crux of what happened was this: the center of gravity in the city moved west and the Sumida became marginalized.[110]

As the east bank of the river was overcome by factories, the west bank was increasingly devalued as further west, urbanizing forces were cohering into a Westernizing "exemplar of

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[108] Fusai Mori and Mohe Subaraya. *Bunken Edo Oezu*. 1858. David Rumsey. *Japanese Historical Maps*. C.V. Starr East Asian Library. University of California, Berkeley. http://japanmaps.davidrumsey.com/luna/servlet/detail/RUMSEY~9~1~22878~90030192:Bunken-Edo-oezu-?sort=Pub_Date%2CPub_List_No%2CSeries_No&qvq=w4s:/where%2FTokyo%2B%252528Japan%252529;sort:Pub_Date%2CPub_List_No%2CSeries_No;lc:RUMSEY~9~1&mi=33&trs=90; "German Map of Tokyo from 1896." *Wikimedia Commons*. https://commons.wikimedia.org/wiki/File:Tokio1896.jpg.

[109] Paul Waley. "The Sumida: Changing Perceptions of a River." *Revue de Geographie de Lyon*, Vol. 65 No. 4 (1990). 261-266.

[110] Ibid, 266.

urban space and city life."[111] As the Sumida was being subsumed into the logic of industrial capitalism, residents migrated west, and urban life distanced itself from the river. These cultural changes were lamented by many Japanese, a tense nostalgia evoked aptly (if romantically) by the novelist Nagai Kafu:

> In earlier days... the naturally flowing Sumida and its many artificial tributaries were the lifeblood of Edo commerce... it provided pleasure for the four seasons and sometimes formed the substance of poems and paintings of some worth. But in today's city of Tokyo, the waterways are simply there for transportation, and they have lost all their former aesthetic value.[112]

The modernization of water in the Meiji period, like Bricktown, helped to lay the foundations for the modern urban climate. Trey Fowler, in summarizing the problem of urban heat in Tokyo, writes that the making of urban heat in Japan must be traced back to the Meiji period: "as Japanese cities modernized around the turn of the century, rivers and all their dirty work were often brushed aside to make way for more illustrious and pleasant things, like roads and buildings."[113] More specifically, urban bodies of water have cooling effects on the environment in two key ways: (1) as sources of evaporation which cool the air above and around them, and (2) as moisture sources that can be evapotranspired by surrounding vegetation.

As discussed earlier, as water evaporates, it transfers heat away from the Earth's surface. During the day, water surfaces and the air above them are significantly less warm than surrounding air due to evaporative cooling. While many see this evaporative cooling as key to the urban heat mitigation potential of water bodies like rivers, at night, these bodies become warmer relative to their environment, due to their high heat capacities, and could actually have a

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[111] Ibid.
[112] Quoted in Paul Waley. *Japanese Capitals in Historical Perspective*, 228. In the chapter, Waley further contextualizes the cultural response to Japan's changing river regime, while like Wilson also emphasizing the continuity of river integration within industrialism.
[113] Fowler, "Urban Heat Islands"

heating effect. While these factors have been seen as ambiguous, and some researchers give more weight to heating effects, others believe that the evaporative cooling potential of water bodies is an important part of heat mitigation. Moreover, the environment surrounding water bodies plays a powerful role in their mitigating influence.[114]

Because winds carry the cool air over rivers across a larger horizontal space adjacent to the river, the organization of that space is an important factor to consider. Japanese scientists have provided key research in this area. Saburo Murakawa and others' studies on the Ota River in Hiroshima City in the 1990s demonstrated that given wind diffusion, evaporative cooling from the Ota had cooling effects for hundreds of meters. However, the potency of those effects depended on the surrounding urban form, namely wider streets and fewer buildings. They concluded that "a well-ventilated city design should be considered to improve the unbearable hot summer environment in Japan."[115]

More fundamentally, and less controversially, water bodies provide moisture that has cooling effects as it is evapotranspired by surrounding vegetation. As Hathway and Sharples suggest, this cooling potential is highly dependent on the land-cover banking the river. In their case study, they suggest with many other researchers that rivers can have cooling effects, but "in order to maximize the benefits of this cooling close consideration of the urban design is required. Highly vegetated banks showed much lower temperatures than those banks consisting of only hard engineering materials."[116]

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[114] Golnoosh Manteghi et al. "Water Bodies an Urban Microclimate: A Review." *Modern Applied Science*, Vol. 9 No. 6 (2015). 1-12. See also Oke et al. *Urban Climates*, 207-208; Gartland. *Heat Islands*, 16.

[115] Manteghi et al. "Water Bodies," 5-8. Saburo Murakawa et al. "Study of the Effect of River on Thermal Environment in Urban Area." *Journal of Architecture, Planning, and Environmental Engineering*, Vol. 415 (1990). 9-19. (abstract in English). Manteghi et al explicitly rely on Murakawa's research in their review.

[116] E.A. Hathway and S. Sharples. "The Interaction of Rivers and Urban Form in Mitigating Urban Heat Island Effect: a UK Case Study." *Building and Environment*, Vol. 58 (2012). 22.

During the Tokugawa era, Edo's urban rivers were surrounded by "dense grassy and bushy vegetation," due to if nothing else the lack of such "hard engineering materials" unlike "dirt, stone, wood, and rope."[117] However, during the Meiji period and after, flood protection and industrialization drastically changed the morphology of these banks. Factories and mills replaced plants.[118] As another novelist at the time, Akutagawa Ryunosuke, lamented, "the occasional sand-banks with their profusion of reeds have been buried without trace."[119] Moreover, the construction of engineered dykes accelerated to protect industry from the rivers' natural flooding, creating a "barrier which was built between the river and its residents."[120] The technological potential of the Meiji period was of course limited in comparison to more recent decades, but the river regime of Tokyo was clearly changing.

In introducing the climatic effects of urban water, Tim Oke in fact uses Tokyo as a paradigmatic case. Looking at a section of the Shibuya River in contemporary Tokyo, Oke takes note of the concrete gutter that guides the narrow river, providing both flood protection and allowing construction right up to the edge of the bank: "in terms of exchanging water with the urban atmosphere, there are few potential sources of water vapor in this image."[121] Vegetation, of course, is sparse. The preceding analysis has shown how the modern water regime, even during the Meiji era, was importantly tied to climatic changes that would accelerate rapidly in the post-war era, producing changes like those described by Oke that Japanese did not understand at the time or prepare for, changes that ultimately undercut Japanese attempts to tame nature.

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[117] Wilson. "The Engineering of Japan's Modern River Regime," 50.
[118] Waley, "The Sumida," 266-270.
[119] Quoted in Ibid, 270.
[120] Bianca Stalenberg and Yoshito Kikumori. "Historical Floods with Responding Flood Control." *Urban Water in Japan*. 97.
[121] Oke et al. *Urban Climates*, 238.

**Greenspaces before World War II**

Like water bodies, *greenspaces*, or vegetated land cover, have an important cooling effect on the environment due to evapotranspiration. Moreover, the replacement of vegetation with urban materials produces heat. Unlike water bodies, whose effects are more controversial, land cover changes are at the center of urban heat science, and the different thermal and moisture properties of rural versus urban land cover are some of the primary mechanisms that produces urban heat. Policymakers and scientists often describe urban "greening" as an important heat mitigation strategy.[122] In Japan, the literature on the relationship between land use and urban heat is profuse and takes a variety of forms: (1) microclimatic comparisons between green versus built-up areas, (2) historical studies that correlate land-use changes and urban heat over time, and (3) numerical modelling comparing hypothetical scenarios with different levels of greenery.

In a landmark 1956 paper, Helmut Landsberg described the cooling effects of urban greenspaces, calling them "nature's air conditioner."[123] Since, urban climatologists have often referred to these areas as "park cool islands" (PCI). In a classic study in 1994, Takashi Hamada and Takehiko Mikami studied the PCI intensities of Meiji Shrine and Yoyogi Park in Tokyo (a measure of their temperature difference with surrounding urban areas), concluding that greenspaces like these reduce nocturnal heat islands. More recent experiments have substantiated these results, using experiments at Shinjuku-Gyoen Park to further clarify greenspaces' cooling effects and pointing to a "seeping-out" phenomenon whereby cool air generated by greenspaces is horizontally distributed, similar to water bodies.[124]

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[122] See Gartland. *Heat Islands*, 16-19, 109-138.

[123] Helmut E. Landsberg. "Nature's Air Conditioner." *Am. For.*, Vol. 62 No. 8 (1956).

[124] Takashi Hamada and Takehiko Mikami. "Cool Island Phenomena in Urban Green Spaces: A Case Study of Meiji Shrine and Yoyogi Park." *Geographical Review of Japan*, Vol. 67 Issue 8 (1994). 518-529. (abstract in English); Yui Nagatani et al. "Analysis of Movement of Cooled Air in Shinjuku Gyoen." *Journal of Agricultural Meteorology*, Vol. 64 Issue 4 (2008). 281-288. (abstract in English); Ken-ichi Narita and Hirofumi Sugawara. "Cold air Seeping Out

Numerical modelling has also pointed to similar effects, as in Tsuyoshi Honjo and Tadashi Takakura's 1990 study on the effects of greenspaces on surrounding areas; others have also used numerical models to clarify the effects of land cover in the Tokyo area, looking instead at how urbanized land cover produces a urban heat in contrast to different sorts of surface cover. Research by Sachiho Adachi and colleagues has used simulations to better understand comparative thermal characteristics of built-up and vegetated projections of Tokyo's future landscape.[125] Finally, historical studies in Japan have also pointed to the importance of land use change, although these have often focused more on the mitigation of the cooling potential of sea-breeze penetration than on vegetation.[126] However, recent studies from many other parts of the world have correlated vegetation loss to an increase in urban heat.[127]

While the industrialization and reengineering of riverbanks worked to bring down the evapotranspirational potential of the landscape, Edo's premodern legacy was itself not altogether

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Phenomenon in an Urban Green Space." *Journal of Geography* Vol. 120 Issue 2 (2011). 411-425 (abstract in English).

[125] Tsuyoshi Honjo and Tadashi Takakura. "Simulation of Thermal Effects of Urban Green Areas." *Energy and Buildings*, Vol 15 Issues 3-4 (1990-1991). 443-446. Fujio Kimura and Shunji Takahashi. "The Effects of Land Use and Anthropogenic Heating on the Surface Temperature in the Tokyo Metropolitan Area: A Numerical Experiment." *Atmospheric Environment*, Vol. 25B No. 2. (1991). 155-164. Sachiho A. Adachi et al. "Moderation of Summertime Heat Island Phenomenon via Modification of the Urban Form in the Tokyo Metropolitan Area." *Journal of Applied Meteorology and Climatology*, Vol. 53 No. 8 (August 2014). 1887; Sachiho A. Adachi and Fujio Kimura. "Comparison of the Impact of Global Climate Changes and Urbanization on Summertime Future Climate in the Tokyo Metropolitan Area." *Journal of Applied Meteorology and Climatology*, Vol. 51 No. 8. (2012). 1441-1454; T. Kinouchi and J. Yoshitani. "Simulation of the Urban Heat Island in Tokyo with Future Possible Increases of Anthropogenic Heat, Vegetation Cover and Water Surface." *Proceedings of the 2001 International Symposium on Environmental Hydraulics* (2001).

[126] Hiroyuki Kusaka et al. "The Effects of Land-Use Alteration on the Sea Breeze and Daytime Heat Island in the Tokyo Metropolitan Area." *Journal of the Meteorological Society of Japan, Series II*, Vol. 78 No. 4 (2000). 405-420; Yoichi Kawamoto. "Effect of Land-Use Change on the Urban Heat Island in the Fukuoka–Kitakyushu Metropolitan Area, Japan." *Sustainability*, Vol. 9 Issue 9 (2017). 1521-1527.

[127] Musa Tarawally et al. "Comparative Analysis of Responses of Land Surface Temperature to Long-Term Land Use/Cover Changed Between a Coastal and Inland City: A Case of Freetown and Bo Town in Sierra Leone." *Remote Sensing*, Vol. 10 Issue 1 (2018). 112-130; Andrew MacLachlan et al. "Urbanisation-Induced Land Cover Temperature Dynamics for Sustainable Urban Heat Island Mitigation." *Urban Science*, Vol. 1 Issue 4 (2017). 38-59; Gartland. *Heat Islands*, 43-46. Los Angeles is a particular stark case of correlation, as temperature trends closely tracked vegetation increases in the early 20th century followed by vegetation loss after the 1930s (p. 46).

antithetical to urban heat. After all, Edo's population expanded rapidly prior to the 1700s, gridded street patterns as in Bricktown long predated 1872, and Edo was certainly a very densely packed city with a dearth of public open space.[128] Still, land cover patterns changed profoundly in the late 19th century: "the main change that accompanied industrialization was conversion of food-producing agricultural land to more direct human uses as a result of urban sprawl and the growth of industrial production."[129]

After the 1870s, Tokyo's population growth not only restarted, but accelerated to unprecedented levels, doubling Edo's high of 1 million by 1905. This growth reflected not only Japan's general population growth due to increased food production and import, but also the increased migration from rural to urban areas.[130] As Kosei Takahashi describes, the rapid expansion of population, in tandem with the development of urban transportation infrastructure, was inimical to the sustenance of greenspaces.[131] Japanese city planners focused largely on modernizing infrastructure, and "its flavor was rationalization of land use for expansion of industry... creating greenbelts and promoting radical zoning initiatives for carving out of the middle of metropolises beautiful natural oases was not really seriously put on the agenda."[132] Waley's characterization of post-war Japanese urban development thus must be extended back into past decades to see how the deeper logic of modernization affected the urban landscape: "the conversion of green into gray."[133]

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[128] See Conrad Totman. *Japan: An Environmental History* (London: I.B. Taurus, 2014). 115-116, 164, 256-257; Sorensen. *The Making of Urban Japan*, 25-39; Thomas R.H. Havens. *Parkscapes: Greenspaces in Modern Japan* (Honolulu: Hawaii UP, 2011). 20-23.
[129] Totman. *Japan: An Environmental History*, 256.
[130] Ibid, 203-207.
[131] Kosei Takahashi. "Greenspace Depletion in Tokyo, Japan." Thesis. Ohio University (2008). 27-29
[132] Carl Mosk. *Japanese Industrial History: Technology, Urbanization, and Economic Growth* (New York: Routledge, 2001). 239.
[133] Waley. *Japanese Capitals in Historical Perspective*, 89.

By the time that the Kanto Earthquake of 1923 destroyed much of the built environment, city planners certainly recognized Tokyo's lack of vegetation. In 1922, less than 2% of Tokyo was classified as parkland, a number low both in real terms and in comparison to contemporaneous greenspace proportions in other cities. While city planners sought to create a greener city from the ashes, greening initiatives in the 1920s and 1930s had little effect and failed in their expensive ambitions, all the while the hard surfaces of roads and buildings continued to proliferate in the years before World War II.[134] While Thomas Havens rightfully argues that Japanese planners tried to create greenspaces, as open spaces to highlight Japan's nascent modern public sphere, the conclusion of a more or less linear decline in greenspaces in the early 20th century cannot be avoided. As one comparative geographic study of the land cover patterns among Asian cities plainly notes, "the most apparent effect of urbanization is the increase of built-up land cover. As the process of urbanization continues, the built-up dominant areas expand and the coverage ratio of built-up land cover type increases."[135]

While most scientific research on land cover evolution in Tokyo has focused on the post-war period, due likely both to contemporary relevance and data availability, some studies have extended the search for trends farther back. One 2018 study by Yukio Himiyama and Tetsuya Fukase has used topographical maps produced by the Geospatial Information Authority in Japan since 1897 to trace these linear trends in Japan's land cover urbanization since 1900, including a

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[134] Charles J. Schencking. *The Great Kanto Earthquake and the Chimera of National Reconstruction in Japan* (New York: Columbia UP, 2013). 154-178, 288-289, 305; Havens, 85-121; Sorensen. *The Making of Urban Japan*, 145-146.

[135] Havens. *Parkscapes*, 1-18. K.S. Cheng et al "Comparing Landcover Patterns in Tokyo, Kyoto, and Taipei Using ALOS Multispectral Images." *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Science*, Vol. 353 Part 8 (2010). 514. Cheng et al's conclusion that "both the landcover type richness and evenness are low in most of the Tokyo study area. The Tokyo study area is highly urbanized and built-up is the single dominant landcover type in almost all cells" (p. 515) seems to be in some tension with Havens' remark that "sometimes maligned for its monotonous stretches of concrete apartment blocks and lack of large countryside parks in its central districts, Tokyo may actually be 'the greenest of big cities'" (p. 4). Perhaps the tension results more from generalization than anything else, but it is nonetheless true that the two points are geared towards very different ways of understanding Japan's modernization.

near doubling in square kilometers and land cover percentage of urbanized surface material between 1900 and 1950 in comparison to falling rates of other land use types.[136] In recent years, the use of historical geographical information systems (GIS) studies like those done by Himiyama, who is at the forefront of the field, have emerged as an exciting subfield, and work in these areas has helped clarify the evolution of land use patterns in Tokyo over time.[137]

Among the reasons that Tokyo city planners sought (albeit with little success) to increase urban greenspaces in the century prior to World War II, namely "hygiene, exercise, disaster-relief as firebreaks and refuge spots, and civic culture,"[138] all were detached from the importance of greenspaces as "air conditioners." Just as humans in this period built modern durable cities, reframed the physical and social geography of rivers, and urbanized land cover with no understanding of the thermal effects of these changes, attempts to mitigate these changes were not done in the interests of mitigating heat, as they are in the 21st century. Unaware of much of the physical attributes of the environments they were creating, built materials, anthropogenic heat, and solar energy generated millions of miles away in outer space entered into complex new material and geometric relationships with each other outside the scope of human intentionality and control.

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[136] Yukio Himiyama and Tetsuya Fukase. "Land Use Change in Tokyo Prefecture Viewed from the Medium Scale Topographic Maps." *Exploring Sustainable Land Use in Monsoon Asia*. Ed. Yukio Himiyama (Singapore: Springer 2018). 211-212.

[137] See David S. Sprague and Nobusuki Iwasaki. "Historical GIS Studies in Japan: Scholarship and Internet Dissemination of the Rapid Survey Maps." *Journal of Asian Network for GIS-based Historical Studies*, Vol. 1 (November 2013). 17-21; Loren Siebert. "Using GIS to Document, Visualize, and Interpret Tokyo's Spatial History." *Social Science History*, Vol. 23 No. 3 (2000). 237-274.

[138] Havens. *Parkscapes*, 33.

## Part 3 – Concrete and Cosmology: The Fabric and Form of Post-War Urban Heat

### The Great Acceleration and the Science-History of Urban Heat

As during the 1923 earthquake, the bombing campaigns of the Pacific War once again levelled Tokyo, a built environment still at that point largely made of timber.[139] Earlier, the Fire of 1872 gave Japanese modernizers the opportunity to test out a very different kind of urban fabric and form. As the urban population increased through the next decades, hard surfaces continued to make inroads to the detriment of "natural" landscapes. While declensionist narratives turn this story into one of nature's subsumption under human forces, whether they be capital, industry, or culture, natural processes continued to develop. By the time Fukui and Wada completed their 1939 experiment, Tokyo had developed a heat island made up of novel configurations of material and spatial forces. However, even by 1945, the progression of modernity into the built forms of the cityscape was limited. Modernization was not a flash but a process, albeit one that was punctuated by the destruction of the city during the war. The high-growth decades that followed not only reproduced the effects of modernization from the pre-war era, but brought them to new heights.

J.R. McNeill and Peter Engelke have described the changing pace of environmental change since 1950 as the "Great Acceleration."[140] The term usefully suggests that the so-called Anthropocene, a term popularized at the beginning of the 21st century to conceptualize the enormous influence humans have had on Earth at a geological level, did not follow a linear development. The half century since World War II has seen unprecedented anthropogenic influence on Earth systems in everything from extinction rates to climate change, both at the

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[139] Sorensen. *The Making of Urban Japan*, 151

[140] J.R. McNeill and Peter Engelke. *The Great Acceleration: An Environmental History of the Anthropocene since 1945* (Cambridge: Harvard UP, 2014). 1-6.

level of the globe and the urban microclimate. It is no surprise that although experimental evidence demonstrated the existence of a heat island in Tokyo prior to World War II, it was really those urban alterations after 1950 that were fundamental to Tokyo's current heat island. In working to explain and speculate on the thermal effects of pre-war modernization, my aim has not only been to better understand the results of those pre-war experiments, but also to show how the logic and trends of modernity in Japan were not merely a post-war phenomena, but one that reached back to the late 19th century. After all, the Great Acceleration was a "jump-start" to the Anthropocene that *sped up* human-driven effects, not a wholly new phenomenon.[141]

After the war reduced Tokyo to rubble and ash, Tokyo's temperature dropped. Matsumoto and colleagues suggest that this cooling may have been the result of the loss in population, and by extension anthropogenic heating from urban activities.[142] However, we might also look at how the bombings changed the urban fabric of Japanese cities, at least for a brief period before rebuilding began in earnest. Writing in the aftermath of the atomic bombs, American journalist John Hersey wrote that "over everything… was a blanket of fresh, vivid, lush, optimistic green."[143] William Tsutsui supports this general observation: "in general, vegetation erupted in profusion in the cities' [Hiroshima and Nagasaki] ruins." As the Great Acceleration was underway in the years after, rebuilding efforts rapidly overtook this sudden outgrowth of vegetated land cover.[144]

Others undertook experiments similar to those of Fukui and Wada later in 1949, and upon discovering similar results, some concluded that urban heat was not solely the result of

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[141] Ibid, 6.
[142] Matsumoto et al. "Urban Climate in the Tokyo Metropolitan Area in Japan," 54.
[143] For the his notable 1946 account, see John Hersey. *Hiroshima* (New York: Vintage, 1989). 69-70. This specific quote I first located in William Tsutsui. "Landscapes in the Dark Valley: Toward an Environmental History of Wartime Japan." *Environmental History*, Vol. 8 No. 2 (2003). 297.
[144] Tsutsui. "Landscapes in the Dark Valley," 297-298.

anthropogenic influence, but due merely to Tokyo's natural geography. The previous year, another researcher presented evidence that Kyoto's urban heat could be best explained by air pollution.[145] Ever since, debates concerning the formation mechanisms involved in urban heat has characterized much of the literature. Over the 1980s and 1990s, Japanese scientists worked to uncover the "individual causations" that produced urban heat, often using simulations to segregate the variable effects of urban density, anthropogenic heat release, and solar reflectance.[146] More recently in 2007, renowned urban climatological researcher Fujibe Fumiake distinguished anthropogenic heat, decreased evapotranspiration, and the change in the heat balance equation as the three determinate factors in UHI genesis. Others have since worked to qualify these results.[147]

A fundamental problem in urban climatology is that scientists tend to causally isolate these factors as if they were discreet. In a comprehensive review from 2010, Mirzaei and Haghighat discuss the limitations of urban heat science methodology, describing the lack of integration of different scales of analysis and an inability to capture the complexity and simultaneity of formation mechanisms.[148] In Oke's words:

> Isolating causes is complicated by the fact that a change in one characteristic of the urban system often leads to modification of more than one process… However, if we ask 'what caused the warming?' the answer is 'everything'; all the modifications mentioned here are probably involved in a complex set of interwoven relations.[149]

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[145] Shitara. "Fifty Years of Climatology in Japan," 401.
[146] Kusaka. "Recent Progress on Urban Climate Study in Japan," 117-119.
[147] Kiyotaka Nakagawa. "Trends in Studies on the Formation Mechanism of the Urban Heat Island in Japan with Special Emphasis on the Relationships between Heat Island Intensity and Boundary Layer of Urban Areas." *Journal of Geography*, Vol. 120 Issue 2 (2011). 255-284 (abstract in English).
[148] Parham A. Mirzaei and Fariborz Haghighat. "Approaches to Study Urban Heat Island – Abilities and Limitations." *Building and Environment*, Vol. 45 No. 10 (2010). 2192-2201.
[149] Oke et al. *Urban Climates*, 40-41.

Here, he touches upon this basic issue of scientific methodology, and it is worth noting that these scientists look critically at their own field. "Science" is not a homogeneous set of practices and conclusions, but a hotly contested area of research, and practitioners themselves open the conversations concerning the limitations and nature of scientific inquiry as much as students of sociology or history. That being said, parochialism can often constrain a holistic and interdisciplinary engagement.

To take an example: in a 1988 paper, Shuji Yamashita presents a chart meant to depict the causes of urban heat (Fig. 1.6). As one can see, these three factors, "population concentration," "modification of Earth's surface," and "expansion of living space," are imagined here as basic factors. From this groundwork, he traces each temporally to their discreet effects on the heat budget. This chart creates a two-sided illusion. First, it disguises the "interwoven relations" that exist between these causes and solar radiation; each is mutually dependent on each other to gain any potency. As described, studies in Japan and elsewhere demonstrated that the evaporative cooling potential of rivers is dependent on both the surrounding urban form and the vegetation cover of the riverbank. Second, it disguises the genesis of these causes, erasing a history of hybrid developments. As I have demonstrated, demographic change, infrastructural modernization, declining greenspaces and water bodies, and the proliferation of heat-trapping fabrics all advanced in a tight symbiotic relationship over the early 20th century.[150]

[150] Naturally, my discussion of urban heat has been selective to some extent. Various factors have not been discussed, although their effects have been significant. Foremost among these is the influence of anthropogenic heat, which Japanese scientists have emphasized to a greater extent than many. While I have been selective, it is also worth noting that anthropogenic heat, like these other factors, developed symbiotically as population growth led to proliferation of cars and air conditioners which produce heat. As seen, this growth was enabled by changes to the urban fabric and form.

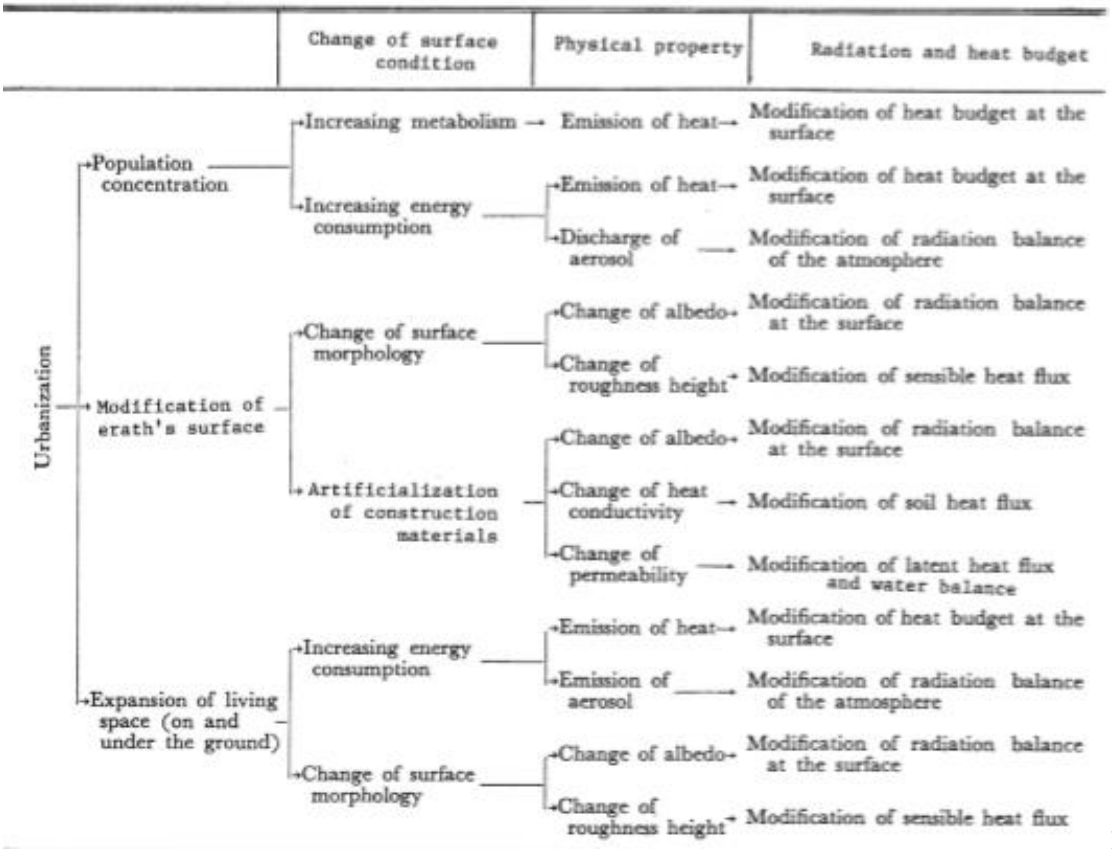


Figure 1.6[151]

It is no surprise that policy recommendations developed from such scientific programs result in piece-meal "mitigation" efforts. The Japanese government's 2004 policy outline discussed at the beginning of the chapter mirrors this science, pointing in a bulleted list format to initiatives involving energy use reduction programs and tree planting to address a list of distinct UHI causes.[152] Trey Fowler looks askance at the effectiveness for such small-scale measures, pointing instead to the larger historical processes that built up Tokyo's heat island, the reversal of which will require more than just cosmetic adjustments.[153]

Ultimately, these concerns suggest the powerful role that integrating history and science can play in the future of our living spaces. On the one hand, historians to date have not taken

[151] Shuji Yamashita. "Some Studies of Heat Island in Japan-With Special Emphasis of the Climatological Aspects." *Geographical Review of Japan*, Vol. 61 Series B No. 1 (1988). 2.
[152] "Outline of a Policy Framework," 4-5.
[153] Fowler, "Heating Up Japan."

seriously the question of why many cities have risen in temperature a few degrees due to localized changes over the past century. On the other hand, the scientists who *have* asked this question have not looked deeply enough into the fundamental nature of the social and material changes associated with modernity. In integrating the two, the fundamental question for the future becomes clearer: what kind of environments do we want to live in and what costs will our decisions entail? In these final sections, I will discuss the developments of urban heat causes over the late 20th century and then tie these developments to the larger cosmological context in which they took place.

**The Power of Concrete and the Convergence of Causes**

In his landmark monograph, *Toxic Archipelago: A History of Industrial Disease in Japan*, Brett Walker coins the phrase "hybrid causation" to describe how "at certain moments in history, historical and natural drivers come together - serendipitously joining forces one might say..."[154] Walker uses this concept to organize his history, showing how biological forces, chemical reactions, political imperatives, and cultural norms all co-produced the phenomena of various industrial illnesses like cadmium poisoning. Walker's history is a powerful example of the kinds of stories one can tell when one takes on board Dipesh Chakrabarty's challenge to weave together human and natural history in the face of the Anthropocene.[155] Hybridity has come to be something of an axiomatic principle in environmental historiography.[156]

[154] Walker. *Toxic Archipelago,* xiii.
[155] Dipesh Chakrabarty. "The Climate of History: Four Theses." *Critical Inquiry*, Vol. 35 (2009). 201-207.
[156] Sara B. Pritchard discusses "hybrid causation" as part of her discussion of the hybrid turn in environmental historiography. "Toward an Environmental History of Technology." *The Oxford Handbook of Environmental History.* 239-240.

However, drawing on the so-called "object-oriented ontology" of Graham Harman among others, LeCain seeks to challenge this orthodoxy. Going back to the development of various materialist social theories in the 1990s, the influence of matter has become rhetorically tied too much to humans. Walker's idea of hybrid causation still gives human actors a central role, even if they do intimately share the stage with silkworms and chemicals. However, the vast majority of material interactions in the universe do not involve humans in important ways.[157] As Walker has written more recently in connection to the "hybrid toxicological qualities" of the asbestos dust that inhered within New Yorkers' bodies in the aftermath of the destruction of the World Trade Center, "inorganic chemistry… became an agent in this historical narrative… not simply the intertwining of politics, science, technology, and nature… but rather… the *material hybridity* that occurred in the multicausal fires" (italics mine).[158]

Even when they do involve people, the role of human agency is often not as central as our histories make it out to be. Urban heat islands are often referred to as "manmade" climates, but this phrase is highly misleading. Yamashita offered some corrective when he wrote in 1990 that "urban climate is one of the most typical examples of environments which man has inadvertently produced," but the anthropocentric notion that humans above all else act to "produce" these climates remains.[159]

Naturally, one can say that cities were built by humans, or more generally that human inhabitancy was the aim of building cities. However, the microclimates produced in cities are not tied to human intentions, and to explain this history, one must understand the properties of and interactions among nonhuman matter. Even if the phrase "manmade" may not really imply

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[157] LeCain. *The Matter of History*, 87-91.
[158] Brett Walker. "Environments of Terror: 9/11, World Trade Center Dust, and the Global Nature of New York's Toxic Bodies." *Environmental History*, Vol. 20, Issue 4 (2015). 783-784.
[159] Shuji Yamashita. "The Urban Climate of Tokyo." *Geographical Review of Japan*, Vol. 63 Series B No. 1 (1990). 99.

intentionality, the lines between human and nonhuman agency seem fragile at that point. If neither humans nor things like solar energy, brick, and concrete played an *intentional* role in bringing about heat islands, the reasons for foregrounding the agency of one over the others seems hopelessly anthropocentric and ahistorical.

If nothing else, what a self-consciously materialist narrative of urban heat provides is an exciting and maybe disconcerting view of a history wherein humans seem to be marginal actors in these historical events much more centered on nonhuman interactions, events that have resulted in global concerns to human health. In these final sections, I will foreground hybrid causations that center nonhuman matter rather than people. First, I argue that the intrinsic power of concrete enabled the Great Acceleration of urban heat after World War II, collapsing the causal paths of various developments together into a unified stream that compounded the interactions with solar energy that produced heat islands.

In a 1979 article, Kiyoshi Okutomi quantified the Tokyo area's vegetation cover and described possible conservation measures in the face of rapid urbanization. In pre-war Tokyo, Okutomi noted, damage to the vegetated growth around Tokyo had been limited. However, since, 1960, he plainly concludes: "Comparing maps or aerial photographs made or taken in past years, it is found that the urbanization of Tokyo has greatly expanded in the years since about 1960 and the vegetation cover of Tokyo has strikingly decreased during this time."[160]

Those who worked to reconstruct Tokyo after World War II did not anticipate this accelerated depletion. Rather, planners imagined an extensive system of parks and greenbelts.

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[160] Kiyoshi Okutomi. "Vegetation of Tokyo and its Conservation and Management." *Bulletin of the Yokohama Phytosociological Society*, Vol. 16 (January 1979). 145, 153. For later studies on urban vegetation indexation, see Tsuyoshi Honjo and Tadashi Takakura. "Estimation of Vegetation Cover Ratio in Urban Area by Using Vegetation Index." *Journal of the Japanese Institute of Landscape Architects*, Vol. 58 Issue 5 (1988). 283-287. (abstract in English); Yujiro Hirano et al. "Pragmatic Approach for Estimation of Vegetation Cover Ratio in Urban Area Using NDVI." *Journal of the Remote Sensing Society of Japan*, Vol. 22 No. 2 (2002). 163-174.

However, these plans came to little due to budgetary constraints, a lack of centralized control, and the exploding post-war urban population which quickly made up for the immediate drop after 1945. In general, rebuilding efforts became haphazard and uncoordinated. By 1950, the rough start date for the Great Acceleration, city planners and building constructers were faced with rapid population influx at a time when the infrastructural capabilities of the city were severely constrained in the wake of war.[161] The efforts to rebuilt Tokyo seemed to lack a centralized developmental framework, but in the 1950s, the novel material context of the rehabilitated cement industry provided the bedrock of not only post-war reconstruction, but unprecedented high rates of growth and modernization.

Concrete and cement were not brand new to Tokyo's planners. Especially after the 1923 earthquake, the durability of reinforced concrete was promoted by planners as advantageous in building an urban fabric that was stronger and more flame resistant.[162] Indeed, cement production was deeply entwined with Japanese empire building in the 1930s as colonial supply chains permitted much greater access to raw materials. Moreover, the construction of colonial cities, such as those in Manchuria, provided urbanization projects to which Japanese civil engineers flocked. These projects arose with the need to build modern cities on the Asian continent, projects that prefigured the rebuilding of Tokyo a few years later.[163]

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[161] Ichikawa Hiroo. "Reconstructing Tokyo: The Attempt to Transform a Metropolis." *Rebuilding Urban Japan after 1945*. Ed. Carola Hein, Jeffry M. Diefendorf, and Ishida Yorifusa (New York: Palgrave. 2003). 50-54.
[162] Peter Armstrong. "Architecture in the Mono-no-nai-jidai." *Legacies of the Asia-Pacific War: The Yakeato Generation*. Ed. Roman Rosenbaum and Yasuko Claremont (London: Routledge, 2009). 217.
[163] Armstrong. *Legacies of the Asia-Pacific War*, 217-218; William Steele. "Constructing the Construction State: Cement and Postwar Japan." *The Asia-Pacific Journal: Japan Focus,* Vol. 15 No. 11 Issue 5 (1 June 2017). 1-2. The term "construction state" was popularized by Gavin McCormack originally, and has been discussed since in both academic and popular literature. See McCormack. *The Emptiness of Japanese Affluence*. Revised Edition (New York: Taylor and Francis, 2001.) 25-77. For a more streamlined account, see Gavin McCormack. "Growth, Construction, and the Environment: Japan's Construction State." *Japanese Studies*, Vol. 15 No. 1 (1995). 26-35. See also Alex Kerr. *Dogs and Demons: Tales from the Dark Side of Modern Japan* (New York: Hill and Wang, 2002). 13-50; Peter McGill. "Paving Japan - The Construction Boondoggle." *Japan Quarterly*, Vol. 45 Issue 4 (1998). 39-48.

However, during the war and occupation, the Japanese empire collapsed, and domestic production of cement stalled. Not until the Korean War jump-started Japanese re-industrialization in the early 1950s did the post-war era of high economic growth begin. The re-emergence of concrete manufacturing occurred alongside these trends. In fact, the demand for cement arising from the war produced a "cement boom" that actually substantially helped to *drive* Japan's economic recovery. In short time, Japanese cement production quickly surpassed its prewar levels with 6.5 million tons in 1951 and more than doubling to 15 million tons by 1957.[164]

But what was this material that, like brick almost a century prior, would come to be of such consequence to the development of Japan's modernity? Concrete is a synthetic substance composed of an *aggregate*, or rocks of varying sizes (such as sands and gravel), and a *binder* that glues the rocks together when water is added. This binder is called cement, and the most common form of cement (Portland cement) was invented in stages in the mid-19th century in England. Chemically, concrete results from the calcium silicates, which make up the cement, mixing with water (a process called *hydration*). The resulting paste (mostly calcium silicate hydrate, C-H-S) binds the aggregate together. The key factor in concrete durability is the ratio between water and cement (w/c) that is used to create the binder, the ideal ratio being one that has just enough water to create the thickest paste possible that is still workable, such that the binder is not diluted by extra water. The w/c ratio determines most of concrete's important qualities that led to its widespread adoption, that is, its *compressive* strength and waterproofness (compressive strength being its ability to withstand pressure from compaction).[165]

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[164] Steele. "Constructing the Construction State," 2-3.

[165] For the most basic introduction, see "Concrete Technology." *Portland Cement Association*. https://www.cement.org/learn/concrete-technology. For more detail on Portland cement from the PCA, see "How Cement is Made." Cement and Concrete Applications. https://www.cement.org/cement-concrete-

However, these properties of durability, in addition to its cheapness and widely available constituent parts, are only part of concrete's power. Like brick, concrete contains certain physical capabilities that make it resistant to change, allowing for the static built environments so necessary to capitalistic modernity. Indeed, concrete possesses these qualities to an even greater degree than brick. However, at the root of concrete's novel power lies not merely its *durability*, but also its *flexibility*:

> Within this process [binding through hydration] lies the key to a remarkable trait of concrete: it's plastic and malleable when newly mixed, strong and durable when hardened. These qualities explain why *one material*, concrete, can build skyscrapers, bridges, sidewalks and superhighways, houses and dams (italics mine).[166]

Throughout the 19th and 20th centuries, people endlessly tinkered with the chemical makeup of concrete to enhance its effects. Additionally, the development of *reinforced* concrete and its spread in the early 20th century was fundamental to its growth. Reinforcement entailed enmeshing concrete while still malleable with a metallic frame which increased the block's *tensile* strength, allowing it to maintain its integrity under elongation stresses and giving it "new loadbearing quality" and a far vaster range of flexible applications.[167] These properties, the results of chemical and environmental interactions, carefully experimented with by humans, allowed concrete to effectively take over the global environment. Not only is concrete by far the

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applications/how-cement-is-made. For much of the same information alongside a historical overview, see S.H. Kosmatka and M.L. Wilson. *Design and Control of Concrete Mixtures*, 16th Edition (New York: Portland Cement Association, 2016). 1-16. For another technically-based historical overview, see Pamela H. Simpson et al. "Concrete Block." *Twentieth-Century Building Materials: History and Conservation*. Ed. Thomas C. Jester (Los Angeles: Getty Conservation Institute, 2014). 47-52 and Amy E. Slaton et al. "Reinforced Concrete." 61-70. For another overview of concrete materials and applications with a more abstract architectural focus, see Andrea Deplazes. *Constructing Architecture: Materials, Processes, Structures: A Handbook* (Basel: Birkhauser, 2005). 56-76. For a more detailed look at the chemical processes involved in hydration, see Mark Alexander et al. *Durability of Concrete: Design and Construction* (Boca Raton, CRC Press, 2017). 11-36.

[166] "Concrete Technology."

[167] Amy E. Slaton et al. *Twentieth-Century Building Materials,* 61.

most common building material across the globe, it is also the second most widely used material *in general* next only to water.[168]

In his classic history of concrete and its integration into modern architecture, Peter Collins describes the events that led to the synthesizing of concrete as "the discovery of a new material."[169] This phrase, *discovery*, is exactly how we should consider the development of concrete. More than anything else, concrete came about when humans *took advantage* of the intrinsic material power embedded within the physical world. Humans did not impose their will on the things around them, shaping them as they desired, as much as they entered into a dialectical relationship with the material physics and chemistry involved. Not only was this relationship between rocks and chemists two-way, but as Adrian Forty emphasizes in his more recent cultural history, it was not just scientific experts who "created" concrete as a modern material, but, in the development of reinforcement, it was largely through the a-theoretical "artisanal experiments" of traditional craftsmen, (i.e. "inserting pieces of iron and steel into concrete and hoping for the best") "that the benefits of steel reinforcement were discovered."[170] The contingencies that led to the discovery of modern concrete's power were more related to accidents and chance encounters than they were to human foresight and control.

Earlier, I described the urban context of post-war Tokyo as essentially the convergence of three trends: (1) the rapid re-population of Tokyo, (2) the lack of infrastructure to contain this swell, and (3) the failure of coordinated control of planning. To these three trends, we must add a

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[168] Alexander et al. *Durability of Concrete*, 1.

[169] Peter Collins. *Concrete: The Vision of a New Architecture*. 2nd Edition. First published in 1959. (Quebec: McGill-Queen UP, 2004). 19-94. For a recent more popular account of the history of concrete, see Robert Courland. *Concrete Planet: The Strange and Fascinating Story of the World's Most Common Manmade Material* (New York: Prometheus Books, 2011).

[170] Adrian Forty. *Concrete and Culture: A Material History* (London: Reaktion Books, 2012). 17-21. Note that "ferro-concrete" and "armored concrete" are basically synonymous with reinforced concrete. In non-technical literature, *cement* and *concrete* are often used interchangeable, but the clear distinction between them has already been drawn.

fourth in order to truly comprehend the developments which followed in the 1950s: (4) the accelerating growth of concrete production as a result of the Korean War.

The convergence of these *four* trends caused the concretization of the landscape:

> By 1950, little of Tokyo was rebuilt according to any sort of comprehensive scheme—and when the reconstruction of Tokyo and other major cities accelerated thereafter, the only general principle in force was the near universal use of cement: building, roads, bridges, sewers, dams, river embankments, docks, sea walls, even cement telephone poles.[171]

Superimposing these four trends, these developments become more predictable. As one journalist described in 1952, "it is almost impossible for the supply of housing to catch up with the increasing population."[172] In the haphazard political context of post-war Japan, *concrete became the organizing force in the development of Tokyo's post-war fabric*. The material pull of this rehabilitated substance was understandably "chosen" by Japanese construction leaders in such an uncertain time; it was highly unlikely that such planners, under the extreme pressure of population growth, would have avoided a thing with such potency, already proven durable enough to outlive most of the firebombing of Tokyo during the war and flexible enough to meet such a variety of infrastructural needs.[173]

As seen, the flexibility of concrete is due to the hydration-based binding process that glues aggregate together, allowing for the all-important period before the mixture sets in which it is malleable. This capacity enabled concrete to singularly embed itself within almost all aspects of the urban fabric and form. Japan's roads, 99% of which were unpaved in 1946, were rapidly covered in concrete, and the same substance provided for the creation of dams and tunnels. Steel

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[171] Steele. "Constructing the Construction State," 4.
[172] From *Asahi Shinbun*, quoted in Kazuo Usui. *Marketing and Consumption in Modern Japan* (London: Routledge 2014). 114.
[173] For the durability of concrete structures during the bombings, see Armstrong. *Legacies of the Asia-Pacific War*, 223.

reinforcement only increased the flexibility of the material, allowing the proliferation of both offices in the very center of Tokyo as well as public housing. These apartment buildings (*danchi*), built as they were out of the quintessential modern material, were themselves symbols of the rising middle-class, nuclear family-based lifestyle, providing the domestic setting for a growing consumer culture.[174] Reinforced concrete also enabled builders to construct high-rises and skyscrapers in the 1960s and 1970s, buildings that not only had thermal properties conducive to urban heat, but geometric ones as well.

Perhaps the seminal development in Tokyo's post-war urbanization, one that general histories often highlight, is Tokyo's sponsorship of the 1964 Summer Olympic Games.[175] Just as in 1872, the need to impress upon Western visitors Tokyo's modernity was at hand. As one resident remembered, his local ward office informed his parents of the need to install modern toiletry in case Westerners were to visit. Likewise, his father worked to learn English to man the train station for visitors. All these motivations revolved around one impending event: "the foreigners are coming."[176] In this vein, Tokyo planners worked rapidly to modernize the city's

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[174] Steele. "Constructing the Construction State," 4-6. Usui. *Marketing and Consumption in Modern Japan*, 114-117. For a recent account, see Laura Lynn Neitzel. *The Life We Longed For: Danchi Housing and the Middle Class Dream in Postwar Japan* (Honolulu: Hawaii UP, 2017).

[175] The 1964 Tokyo Olympic Games have received scholarly coverage from multiple angles. For some concentrated analysis, see Christian Tagsold. "Modernity, Space and National Representation at the Tokyo Olympics 1964." *Urban History*, Vol. 37 Issue 2 (2010). 289-300; Bruce Suttmeier. "On the Road in Olympic Era Tokyo." *Cartographic Japan: A History in Maps*. Ed. Karen Wigen et al (Chicago: Chicago UP, 2016). 210-213 as well as other chapters and articles cited below. More a popular account, see Alexander Martin. "The 1964 Tokyo Olympics: A Turning Point for Japan." *Wall Street Journal*. 5 September 2013. https://blogs.wsj.com/japanrealtime/2013/09/05/the-1964-tokyo-olympics-a-turning-point-for-japan/.

[176] The account I paraphrase here is quoted in Satoshi Shimizu. "Rebuilding the Japanese Nation at the 1964 Olympics: The Torch Relay in Okinawa and Tokyo." *The Olympics in East Asia: Nationalism, Regionalism, and Globalism on the Center Stage of World Sports*. Ed. William W. Kelly and Susan Brownell (New Haven: Yale Council on East Asian Studies, 2011). 42.

infrastructure, completing many now well-known features of the landscape, including the famous *Shinkansen* bullet-train tracks running from Tokyo to Osaka and the Tokyo Expressway.[177]

In all the urbanizing developments that preceded the games, concrete played a central material role. Concrete paved the new roads and upheld the new bridges. Naturally, the stadiums that were built to house the events, the most symbolic presentations of Japan's modernity, were largely built from reinforced concrete.[178] As concrete structures pervaded the urban fabric, the decline of rivers and vegetation accelerated. Many of the lost or fragmented rivers so often mourned in the nostalgic imagination were paved over leading up to the Games for infrastructural projects which continued to marginalize greenspaces as well.[179] As Rebecca Milner notes in her piece on Tokyo's invisible rivers: "in 1960s Tokyo, there was nothing so romantic as progress."[180]

The flexible power of cement worked in post-war Tokyo to entangle the strands of heat-inducing developments together into a single event: the concretization of Tokyo. Like brick, concrete has thermal and moisture properties associated with UHI effects. Those properties are largely tied to concrete's durability, and it was the conjunction between concrete's flexibility and durability that gave it such a power over human decision-makers and the thermal environment.

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[177] Organizing Committee for the Games of the XVIII Olympiad. *The Games of the XVIII Olympiad, Tokyo 1964: The Official Report of the Organizing Committee* (Tokyo: Organizing Committee for the Games of the XVIII Olympiad, 1964). 47-49; Sorensen. *The Making of Urban Japan*, 191-193. Yasushi Aoyama. "Tokyo 2020." *Olympic Cities: City Agendas, Planning, and the World's Games, 1896-2020*. Ed. John R. Gold and Margaret M. Gold. 3rd Edition (New York: Routledge, 2017). 429-437.

[178] Organizing Committee for the Games of the XVIII Olympiad. *The Games of the XVIII Olympiad*, 113-164; Sorensen. *The Making of Urban Japan*, 191-193; For a retrospective account from one American resident of Japan in the 1960s, see Robert Whiting. "Negative Impact of 1964 Olympics Profound." *Japan Times*. 24 October 2014. https://www.japantimes.co.jp/sports/2014/10/24/olympics/negative-impact-1964-olympics-profound/#.XGxvtehKjIU.

[179] Takahashi. "Greenspace Depletion," 27-29; Lili and Berwert, 77-78. Rebecca Milner. "Rediscovering Lost Tokyo." *Japan Times*. 9 July 2014. https://www.japantimes.co.jp/life/2014/07/19/lifestyle/rediscovering-lost-tokyo/#.W72Pb_ZRfIU.

[180] Milner, "Rediscovering Lost Tokyo."

As concrete was cohering the urban fabric, it was intensifying the relationships between the city form and the sun, a relationship external in most significant respects to human agency, yet still of great historical importance.

**Placing the Sun: A Cosmic Geography of Urban Heat**

In order to accommodate the expected influx of tens of thousands of foreign visitors for the 1964 Olympic Games, Tokyo planners worked to modernize the city's living arrangements. After the Building Standard Law Enforcement Order was revised in 1963 to make room for taller buildings, Yonetaro Otani oversaw the creation of the New Otani Hotel. A few years later, Tokyo saw its first "skyscraper," at 147 meters, the Kasumigaseki Building. Both of these buildings were made from steel, because planners were uncomfortable with the capacity of reinforced concrete to withstand earthquakes. However, further experimentation after 1968 improved the resilience of the material, and from the 1970s onward, reinforced concrete enabled the vertical transformation of Tokyo from a low-rise to a high-rise city.[181]

In line with these changes, urban heat was significantly a 3-dimensional phenomenon. In other words, the objects and forces that lead to UHI effects (urban fabric, sunlight, etc) do not interact in a void, but within a constructed geometrical space. Most important to this urban form is the development of the tall and narrow street canyons mentioned earlier. The description of Ginza Bricktown prefigured such canyon developments, although the broad width of its streets

[181] "About Us: History." *The New Otani: New Otani Hotels*. https://www.newotani.co.jp/en/tokyo/about-us/; "About TTK: Constructing High-Rise Buildings in Earthquake-Prone Japan." *Tokyo Tekko*. http://www.tokyotekko.co.jp/en/about/01.html; Shunsuke Otani. "Japanese Seismic Design of High-Rise Reinforced Concrete Buildings – An Example of Performance Based Design Code and State of Practices." *13th World Conference on Earthquake Engineering*, Paper No. 5010. (2004); Evelyn Schulz. "Mapping Environments of Memory, Nostalgia, and Emotions in Tokyo Spatial (Auto)biographies." *Tokyo: Memory, Imagination, and the City*. Ed. Barbara E. Thornbury and Evelyn Schulz (Lanham: Lexington Books, 2018). 69-96

mitigated street canyon thermal effects. The geometrical properties of street canyons and the tall buildings that make them up are important in a couple ways. First, they act as windbreaks and restrict airflow within the environment, air which lifts moisture and heat away from the surface. Second, they work as heat trapping mechanisms as solar energy is reflected off the surfaces of walls and roads and ends up being stored within the canyon. Later at night, limited access to the air from the surface restricts heat transfer, a limitation described as a sky-view factor.[182]

All of these factors have been studied in the context of Tokyo's urban form. Many researchers in the last 15 years, dissatisfied with numerical simulations that focused on anthropogenic heat, created more complex models that took into account canyon structures. The effect of building density on airflow has received particular attention, and Murakawa and his colleagues' conclusion that evaporative cooling potential relied on the surrounding urban form has been described already. Because the effect of canyon structures is often dependent on the ratio between building height and street width, the development in many parts of Tokyo of narrow streets and mutually facing high-rise offices and condominiums provided the spatial context for Tokyo's urban heat island.[183]

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[182] Oke et al. *Urban Climates*, 21-23, 170-171.

[183] See ft. 122 for sea-breeze effects from Tokyo Bay. For some studies, see Shuji Yamashita et al. "Relationships between Heat Island and Sky-View Factor in the Cities of Tama River Basin, Japan." *Atmospheric Environment*, Vol. 20 No. 4 (1986). 681-686; Hiroaki Kondo et al. "Development of a Multi-Layer Urban Canopy Model for the Analysis of Energy Consumption in a Big City: Structure of the Urban Canopy Model and its Basic Performance." *Boundary Layer Meteorology*, Vol 116 Issue 3 (2005). 395-421; Takayuki Tokairin et al. "Numerical Study on the Effect of Buildings on Temperature Variation
in Urban and Suburban Areas in Tokyo." *Journal of the Meteorological Society of Japan*. Vol. 58 No. 5 (2006). 921-937; Hiroyuki Kusaka and Fujio Kimura. "Thermal Effects of Urban Canyon Structure on the Nocturnal Heat Island: Numerical Experiment Using a Mesoscale Model Coupled with an Urban Canopy Model." *Journal of Applied Meteorology and Climatology*, Vol. 43 No. 12 (2004). 1899-1910; Yukitaka Ohashi. "Influence of Air-Conditioning Waste Heat on Air Temperature in Tokyo during Summer: Numerical Experiments Using an Urban Canopy Model Coupled with a Building Energy Model." *Journal of Applied Meteorology and Climatology*, Vol. 46 No. 1 (2007). 66-81.

Despite LeCain's focus on the intrinsic properties of matter, what the important geometric context of urban heat reveals is that it is not only the *intrinsic* capacities of matter that are of significance, but the spatial relationships *between* objects that bring out these capacities in certain ways and help to create them. It is the geometry of the city, as much as its materiality, which drives urban heat.[184]

At the broadest and most important level, it is the spatial relationship that the sun bears to the Earth that drives urban heat. Reducing the "thing-power," of solar energy to its inherent traits cannot explain the genesis of urban heat.[185] Solar radiation enters into Earth's atmosphere with a directionality, allowing it to enter into urban environments at angles that produce the heat-trapping effects integral to heat islands. On another level, urban heat researchers, Japanese and otherwise, recognize the significant *diurnal* behavior that regulates heat islands, that is, temporal patterns that reflect day/night variations (as well as patterns that evolve throughout the morning and afternoon). Heat islands are most apparent on calm nights, when the trapped heat within canyons is slowly released in comparison to flatter rural areas. In Tokyo, these "tropical nights," are a primary source of thermal discomfort related to urban heating.[186] In the context of the solar system as whole, these day/night differences are a spatial process, governed by the Earth's rotation and its place in relation to the sun.

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[184] LeCain does write about spatial relationships when he discusses the influence of copper, but his argument is that copper enabled energy transfers from a distance to become largely invisible, thus making the spatial relationships between humans and their power sources invisible. In other words, intrinsic material capabilities affected space (*The Matter of History*, 272-290). Here, I am arguing instead that spatial arrangements affected material capabilities

[185] LeCain borrows the term "thing-power" from Jane Bennett, and uses it as a fundamental part of his synthesis (*The Matter of History*, 82, 128-132). For the original usage, see Jane Bennett. *Vibrant Matter: A Political Ecology of Things* (Durham: Duke UP).

[186] See Fowler, "Heating Up Japan"; Oke. *Urban Climates*, 216-218 esp.; Adachi et al. "Moderation of Summertime Heat Island Phenomenon"; Kusaka and Kimura, "Thermal Effects of Urban Canyon Structure on the Nocturnal Heat Island"; Yusuke Nakamura. "Extraction of Diurnal Variation Patterns of the Heat Island Intensity by the Fixed Point Observation and Multivariate Analysis in August, 2013 in Kumagaya, Japan." *9th International Conference on Urban Climate* (2015).

Urban heat was not the only geometric pattern in Earth-space that the development of concrete-based high-rise development in Tokyo generated. If the importance of Earth-space geometry seems obscure, the "sunshine rights" movement in the 1970s signals a more obvious instance of it. As those same heat-trapping canyons developed while buildings got taller, Tokyo residents found themselves literally overshadowed by this unregulated vertical growth. As high-rise development blocked sunlight, citizens came together to challenge this disruption to their health, comfort, and overall standard of living, ultimately pushing for state protection of their sunshine rights (*nisshoken*), a novel political concept driven by the changing form of Earth-space.[187] More clearly in this case, one can see how the *geometry* of the relationship between Earth and the sun bore on how people were affected by urban form. Buildings blocked sunlight less because of the intrinsic properties of sunlight and concrete than the spatial relationship between the sun, high-rises, and the living spaces of poorer urban residents who could not escape these shadows.

The postwar urbanization patterns in Tokyo drove changes not just on the surface of the Earth, but reorganized the relationships that existed in the spatial context of the solar system as a whole, what I term the *cosmic geography* of Earth-space. After the Apollo 11 launch, Buckminster Fuller wryly noted that "we are already in space," hoping to call attention to the shared resources of the planet that humanity had to work cooperatively to sustain on so-called

[187] In previous drafts, the history of sunshine rights occupied a great portion of this chapter. Sunshine rights give more clarity to the cosmic geography context. Additionally, the reconfiguration of relationships between residents, political and business powers, and sunlight in this period is useful to understand the effects of modernity on space power. For more on sunshine rights, see Sorensen. *The Making of Urban Japan*, 254-255. For the classic analysis, see McKean. *Environmental Protest and Citizen Politics in Japan*, 112-115. For the most comprehensive work in English that I have found, see Shohei Koike. "Public Choice of Property Rights to Sunlight: A Study of Japanese Sunshine Rights." PhD Diss. University of Oregon (1984). For a legal review, see Sara C. Bronin. "Solar Rights." *Boston University Law Review*, Vol. 89 (2009). 1217-1263.

"Spaceship Earth."[188] In this chapter generally and this section particularly, I have tried to tease out the implications of this statement. Being in outer space matters, not only in the large macro-historical setting of the origins of life and energy on Earth, but in the most micro-historical of circumstances: the modernizing urban form of postwar Tokyo; the geometry of city blocks; drying laundry on an afternoon outside a western-facing apartment.[189] Cosmic geography is not just "big history"; cosmic geography is deeply intertwined with every level of society and every scale of historical time. It is in fact "part of an environmental history that recognizes our place within an immense cosmic environment."[190]

**Conclusion: Toward a Heliotropic History**

In plant biology, heliotropism denotes the patterns by which plants grow and turn to follow the sun. More generally, this phenomenon is termed phototropism as it is apparent with any light source. Explanations of this phenomenon in the history of Western thought varied between strict mechanistic explanations and those that gave more due to plants' sensitivity. In the 16th century Giambattista della Porta argued that heliotropism resulted from "sympathy," a fundamental natural law that governed phototropism, magnetism, and animal behavior. After the Enlightenment, stricter mechanistic explanations came to the forefront: phototropism was simply a response deterministically stimulated by sunlight. However, more recently again, experimental evidence and greater knowledge of plant biochemistry has driven scientists towards a less deterministic explanation, wherein phototropism is not merely a mechanistic effect of photo-

[188] Al-Rodham. *The Palgrave Handbook*, 123-166. For Fuller's work more generally, see R. Buckminster Fuller. *Operating Manual for Spaceship Earth.* First published in 1968. (Oslo: Lars Muller, 2008).
[189] See LeCain. *The Matter of History*, 109 for a discussion of scale.
[190] Degroot. "'A Catastrophe Happening in Front of Our Very Eyes,'" 41. For "big history," see David Christian. *Maps of Time: An Introduction to Big History* (Berkeley: Regents of the University of California Press, 2011).

stimulation, but a sensitive internal response of plants to environmental conditions, a response that is contingent on a complex of factors.[191]

This somewhat obscure scientific history mirrors in significant ways the concerns of determinism that shadow the historiography of environmental studies. Geography is not destiny, but environmental conditions have a significant influence over humans, and humans and cultures do actively respond to these factors. It is somewhere in between anthropocentric fetishizations of human agency and the supposed lifelessness of the world of things that we should place the history of life and all manner of material things on Earth. Like plants, human societies have always patterned their behaviors according to solar resources, whether in terms of agricultural cycles, circadian rhythms, or the ancient energy of fossil fuels. As Dagomar Degroot suggests, "if the sun is responsible for natural changes on our planet, should not its dynamics... be incorporated into environmental history."[192] Moreover, as Lisa Ruth Rand has shown more substantially, the Earth-Sun Connection, as astronomers refer to it, has played an important historical role, for example in the fluctuating solar cycles that continuously alter the near-Earth environment, sending man-made satellites throughout the late 20th century cascading back into the planet and into a tense Cold War geo-political climate.[193]

However, rather than view humans and plants analogously, we should instead posit the sun as a powerful organizing principle for life in general; are they really analogous in the literary sense when the same object relates to both (human is to sun as plant is to sun)? Moreover, as Karen Barad argues, thinking in terms of analogies serves the purpose of systematically reifying

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[191] Craig W. Whippo and Roger P. Hangarter. "Phototropism: Bending towards Enlightenment." *The Plant Cell*, Vol. 18 Issue 5 (2006). 1110-1119.
[192] Degroot. "'A Catastrophe Happening in Front of Our Very Eyes,'" 24.
[193] Rand. "Falling Cosmos," 81-84. For more on this connection, see Holly Zell. "NASA - Sun-Earth Connection." *NASA*. Last updated 7 August 2017. https://www.nasa.gov/mission_pages/themis/auroras/sun_earth_connect.html.

the boundaries between human and nonhuman.[194] In reading history heliotropically, this boundary blurs, and the history and cosmic geography of urban heat demonstrates the powerful role that solar energy played in the history of Tokyo's climate. In the next chapter, I will continue to zoom out to the history of meteorology and the space power of the near-Earth orbit.

[194] Karen Barad. *Meeting the Universe Halfway: Quantum Physics and the Entanglement of Matter and Meaning* (Durham: Duke UP, 2007). 7.

# Knowing Nature: Satellite Remote Sensing and Earth-Space Epistemologies

## Introduction: The 2018 West Japan Floods

In July of 2018, a few days after I left the Kansai region in western Honshu to return to Keio University in Tokyo, Japan was hit with its worst flooding disaster in more than 30 years. Rains pummeled western Japanese prefectures, producing floods and landslides that killed more than 200 people and caused damages exceeding $2 billion. Even after the rains stopped, the intense heat wave hardened the muddy remains, making recovery difficult as Japanese citizens searched for belongings and family members in the rubble. The record-breaking heat also strained the already damaged water supply, leading to difficulties in providing for hydration and hygiene.[195]

Even at a meteorological level, the causes of the floods were hybrid events, a reminder that nonhuman-nonhuman interactions produce history as much as human-nonhuman ones. The intense rains were caused by the interplay between Typhoon Prapiroon, which began to dissipate in early July, and the seasonal Baiu monsoon front which drifted through in its wake. The enormous amount of rainfall was ultimately due to the interactions between the leftover moisture from Prapiroon and the predictable monsoon.[196] It is not just that *both* events occurred, accumulating to produce heavy rainfall. Rather, the two meteorological objects produced effects *through* one another, serendipitously joining forces.

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[195] See Jessie Yeung. "Japan Floods: Heat Wave Adds to Misery in Devastated Areas." *CNN*. 16 July 2018. https://www.cnn.com/2018/07/16/asia/japan-heat-wave-intl/index.html; "West Japan Flood Victims Still Living in Despair a Month after Disaster: Survey." *Japan Times*. 6 August 2018. https://www.japantimes.co.jp/news/2018/08/06/national/west-japan-flood-victims-still-living-despair-month-disaster-survey/#.XAxHwnRKjIU; "Japan Faces $2bn Price Tag for Flood Rebuilding." *Nikkei Asia Review*. 20 July 2018. https://asia.nikkei.com/Politics/Japan-faces-2bn-price-tag-for-flood-rebuilding; "AIR Worldwide Estimates Insured Losses from Japan Floods Could Reach US$4B." *Insurance Journal*. 21 August 2018. https://www.insurancejournal.com/news/international/2018/08/21/498685.htm.

[196] "Major Flooding Inundates Parts of Japan; 126+ Dead." *Aon Benfield Impact Forecasting Reports*. http://catastropheinsight.aonbenfield.com/reports/20180709-1-cat-alert.pdf?utm_source=slipcase.

However, it was not just meteorological phenomena that produced disaster. It may be tempting to see the disaster as a function of rainfall amounts. Many reports of the floods did just that, such as NASA's satellite generated estimates, uncovering the "deadly amounts of rain" Japan received in early July (Fig. 2.1).[197] These reports reify a notion that the floods were a "natural disaster," caused by phenomena outside of the social sphere. This is not the case. As other journalists and analysts pointed out, the deforestation of Japan's mountainsides through urbanization have depleted their ability to retain rainfall, leading to loose soil that is easily dislodged during heavy rain and slides down in landslides.[198] More broadly, as Japanese officials recognized the increased frequency of such disasters, others pointed explicitly to anthropogenic climate change as a driving force of many such high-magnitude events, catalyzing the need for greater mitigation efforts.[199] However, even this term, "mitigation," obscures the social causes of disaster, as it implies that natural events are the basic causes of disaster while infrastructure and social relationships can serve at best to lessen, but not contribute to, the impact of such powerful events.

The way that many people thought about the causes of the disaster revolved around the question of why so many people died. As one reader commented on a news report, "something went wrong with weather reports, emergency warnings, and evacuation. These poor people

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[197] "Severe Rainfall and Flooding in Japan." *NASA Earth Observatory*. https://earthobservatory.nasa.gov/images/92397/severe-rainfall-and-flooding-in-japan.

[198] Linda Sieg. "This is Why Japan's Floods Have Been So Deadly." *World Economic Forum*. 12 July 2018. https://www.weforum.org/agenda/2018/07/japan-hit-by-worst-weather-disaster-in-decades-why-did-so-many-die/; Hemant Nagpal et al. "Japan: Waking Up to Flood Disaster." *Risk Management Solutions Blog*. 3 August 2018. https://www.rms.com/blog/2018/08/03/japan-waking-up-to-flood-risk/.

[199] Kiyoshi Takenaka and Issei Kato. "Japan Faces 'Frequent' Disasters as Flood Toll Reaches 200." Reuters World News. 12 July 2018. https://www.reuters.com/article/us-weather-japan/japan-faces-frequent-disasters-as-flood-toll-reaches-200-idUSKBN1K20BJ; Marie Tanao. "Deadly Rains in Japan Point to Growing Impacts of Climate Change." *350.org*. 11 July 2018. https://350.org/deadly-rains-in-japan/. Karyn Nishimura-Poupee and Hiroshi Hiyama. "Japan Resilient, but Climate Change Making Disasters Worse: Experts." *Phys.org*. 7 September 2018. https://phys.org/news/2018-09-japan-resilient-climate-disasters-worse.html.

should not have died."[200] However, the Japanese Meteorological Agency *did* warn of "catastrophes of extraordinary magnitude" leading up to the disaster, and while a lack of early warning may have played some role, other causes were at play as well.[201] Socioeconomic factors had a great deal of influence, as those at greatest risk were those socially vulnerable: the poor, elderly, and disabled.[202] Additionally, many local governments had only very recently produced hazard maps for the areas, meaning that these areas were already highly built up and that locals were often unaware of the risks they faced.[203] These people died in part as a result of environmental injustice.

[200] Kiyoshi Takenaka and Issei Kato. "Abe Visits Flood Disaster Zone; New Warnings Issued." *Japan Today*. 11 July 2018. Comment by "Marie." 11 July 2018. https://japantoday.com/category/national/update-1-japanese-pm-visits-flood-disaster-zone-new-warnings-issued.

[201] "Japan Floods: Why is the Country Experiencing Record Rainfall?" *Al-Jazeera News*. 9 July 2018. https://www.aljazeera.com/news/2018/07/japan-floods-country-experiencing-record-rainfall-180709091340526.html.

[202] Leo Lewis and Kano Inagaki. "Japan's Ageing Population Hit Hardest in Deadly Flood Crisis." *Financial Times*. 13 July 2018. https://www.ft.com/content/dc399aea-8671-11e8-96dd-fa565ec55929.

[203] Linda Sieg "Japan Hit by Worst Weather Disaster in Decades: Why Did so Many Die?" Reuters World News. 11 July 2018. https://www.reuters.com/article/us-weather-japan-explainer/japan-hit-by-worst-weather-disaster-in-decades-why-did-so-many-die-idUSKBN1K10ET; Nagpal et al. "Japan: Waking up to Flood Disaster."

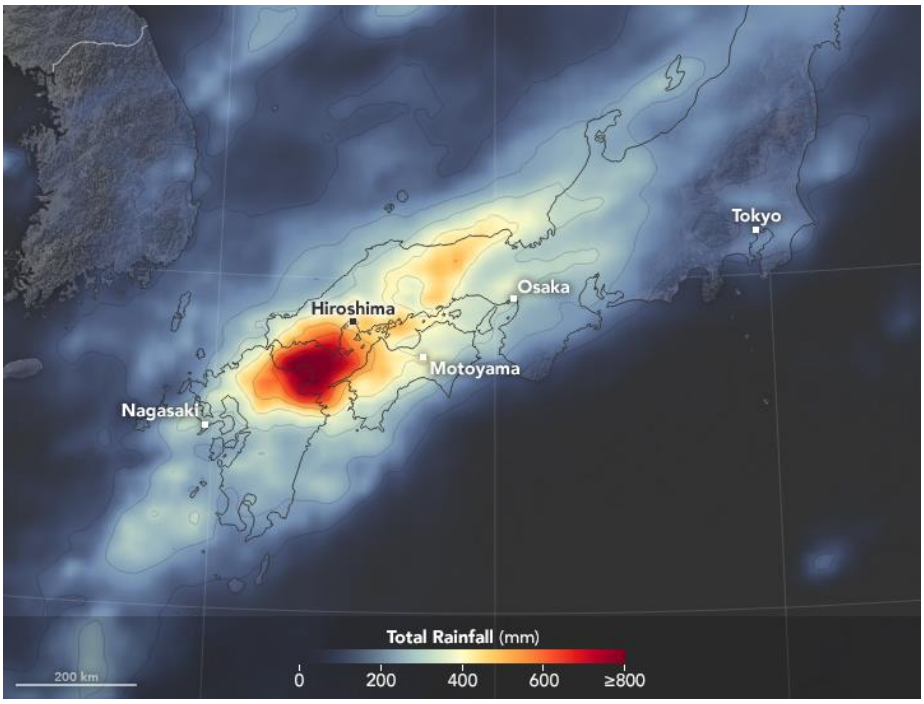


Figure 2.1[204]

As I woke up every morning to new reports of the disaster, other patterns emerged which highlighted another reason that there were so many fatalities. Interviewed survivors often reported that they did not really understand the risks or were not convinced of their potency. Many had memories of previous rainfall in the area and did not see that this event was any different. Others waited to "see how things developed." For whatever reasons, many of those who died had simply ignored evacuation warnings. These residents had privileged their sensations and past lived experiences over the pronouncements of experts.[205] Not only were natural and socioeconomic factors at work, but psychological and epistemic ones were as well. People died in part because of the incompatibility between the way meteorologists have come to

[204] "Severe Rainfall and Flooding in Japan."

[205] Nishimura-Poupee and Hiyama. "Japan Resilient"; Jack Board. "'I Watched My Neighbour Get Swept Away': Japan Flood Survivors Recall Horrors amid Search for Survivors." *Channel News Asia*. 11 July 2018. https://www.channelnewsasia.com/news/asia/neighbour-swept-away-japan-flood-survivors-recall-horrors--10521164; Justin McCurry. "'I Saw My House Sink': Japan Takes Stock after Deadly Rains." *Guardian*. 10 July 2018. https://www.theguardian.com/world/2018/jul/13/i-saw-my-house-sink-japan-deadly-rains-search-extreme-weather; "A Week after Japan Floods, Breakdowns in Preparation Clear." *Nikkei Asian Review*. 14 July 2018. https://asia.nikkei.com/Location/East-Asia/Japan/A-week-after-Japan-floods-breakdowns-in-preparation-clear2.

understand and explain weather phenomena and the way laypeople do, the latter working from the confines of their bodies and limited surroundings while the former extend their epistemic abilities through networks tying a huge amount of data spanning Earth-space to sets of abstract predictive equations.

In this chapter, I will explore the history of meteorology and weather forecasting in Japan since 1883, when the first telegraphic weather map was produced in the country. I argue that the development of modern meteorology was based on core advances which abstracted scientific meteorology away from the embodied experiences of laypeople. In doing so, it produced an incompatibility which generated an epistemic gap that challenged officials' ability to respond to natural disasters and keep people safe. Moreover, technological advances at times generated new weather-related risks in the way they interacted with laypeople's cognition over time. Finally, the development of satellite remote sensing at the end of the 20$^{th}$ century often failed to capture the reality on the ground where natural and social phenomena co-produced events. I track the development of modern meteorology in Japan through the lens of Earth-space to show that technological and epistemic changes associated with meteorological modernity did not always entail a straightforward progression in humans' ability to control nature, but could create new control gaps, new risks, and new failures to understand a hybrid reality.

In Part 1, I will explore the historical background of satellite meteorology in Japan in a framework analogous to that used for examining the growing use of concrete in Chapter 1. I argue that modern meteorological theory depended fundamentally on two epistemic components I term *synopticism*, which allowed scientists to know weather phenomena on a vast scale, and *quantification*, which allowed scientists to know weather through numerical representation. While these epistemic components evolved over time, the development of telegraph-based

weather maps in the 19th century and so-called "numerical weather prediction" (NWP) in the 1950s allowed for additional advances in meteorological theory that broke sharply with past epistemic capabilities. In this part, I home in on the creation of the first weather map in Japan in 1883 and the Japanese contribution to numerical weather prediction in the post-World War II decades as representative of the modernization of Japanese and global meteorology. Satellites, like concrete, served to cohere these developments in the 1960s-1970s, as they provided a large scale (synopticism) of data that could be assimilated into numerical algorithms (quantification) to greatly enhance their predictive power. This part thus concludes with an analysis of Japanese contributions to satellite meteorology, focusing on the development of its first weather satellite, *Himawari I*, in 1977 as part of the Global Weather Experiment, sometimes referred to as the First Global Atmospheric Research Project (GARP) Experiment (FGGE).

In Part 2, I explore the incompatibility that modern meteorology generated between experts and laypeople since the 1980s, borrowing the notion of *incommensurability* from the philosophy of science to explain this gap. Using an interdisciplinary approach that integrates philosophy, sociology, psychology, and history, I explain how this incommensurability produced a need to translate between scientific and lay idioms, a need that is only recently being seriously addressed by cutting edge work in the social sciences. While I will not argue here, as I did in Chapter 1, that people *generally* lost control of the weather, control gaps did emerge which *were a function* of the modernization of meteorology, belying the myth that modernization merely generated enhanced controlling capabilities. Additionally, satellite meteorology supported the development of certain modes of so-called "deterministic" forecasting that contemporary scholars largely agree restrict the communicative potential and flexibility of those forecasts. Finally, not only were new control gaps generated, but new risks could also be created. I will

analyze this aspect through the sociological notion of *warning fatigue*, both generally and in Japan, as a risk that modern methodologies and predictive powers of weather forecasting create in the way they interact with individuals' cognitive abilities.

In Part 3, I turn to a specific case study of InSAR (interferometric synthetic aperture radar) satellite analyses of the Kobe Earthquake after 1995. Here, I argue that these analyses were subjective in important ways that served to reify a socially constructed notion of "natural disaster." After a detailed analysis of the scientific work as well as the technological apparatuses themselves that were as subjective as the scientists, I turn to the messy reality of the disaster itself. Here, I draw on interactionist frameworks to understand the hybrid natural and social levels at play, ultimately arguing that modern science has often not created more accurate images of nature over time, but has created dubious distinctions between the social and the natural world that older theories of disaster in East Asia often blurred. In upholding these distinctions, the modern science of satellite remote sensing fails to offer the political impetus that many premodern societies had to fault their leaders for natural disasters and rebel against perceived environmental injustices. In this way, modern epistemologies constrain the ability of individuals to control and act against the deadly interactions between society and nature. While in the previous chapter I focused on the interplay between natural forces and objects, in this chapter I will reintegrate the human and social into the hybrid networks that drive many historical events.

## Part 1: Synopticism and Quantification, 1883-1980

### The Weather Map

In comparison to other scientific fields, meteorology has received very little scholarly attention from historians, although the subfield has expanded greatly since the 1980s. This lack of attention may have to do with the novelty of the science, which only emerged as a unified field in the 20th century, a perceived lack of rigor, and the historically "ill-defined" boundaries of the field.[206] The International Commission for the History of Meteorology (ICHM) was only founded in 2001, and to date has published only 8 volumes of its journal, *History of Meteorology*.[207] In comparison to the phenomenon of urban heat however, there is a vast amount of non-scientific literature available, much of which I have used tried to integrate in this chapter. Even less work has been done on the history of Japanese meteorology specifically, and no general studies of the topic in English have been done to my knowledge.[208] My analyses here will be by no means an overview of either the history of meteorology in general or even the Japanese case particularly. Rather, I will give a series of snapshots that represent fundamental aspects of what meteorological modernity meant in Japan and elsewhere.

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[206] For a brief interpretation of the lack of interest in the history of meteorology, see Craig Martin. *Renaissance Meteorology: Pomponazzi to Descartes* (Baltimore: John Hopkins UP, 2011). 14-16; Katharine Anderson. "Meteorology." *Reader's Guide to the History of Science.* Ed. Arne Hessenbruch (London: Fitzroy Dearborn Publishers, 2000). 476-477. For a recent bibliography, see Brant Vogel. "Bibliography of Recent Literature in the History of Meteorology Twenty Six Years, 1983-2008." *History of Meteorology*, Vol. 5 (2009). 23-125.

[207] "International Commission on the History of Meteorology." About. http://meteohistory.org/.

[208] Masumi Zaiki and Togo Tsukahara are some of the few scholars writing in English I have come across. Zaiki will be cited later in more depth, as his work on historical climatology has uncovered much of what little data is available concerning premodern Japanese meteorological measurements and instruments. Tsukahara largely works in the history of medicine and science and has occasionally worked on meteorology. Likewise, some of his work will be cited in more detail later. For their most explicit historical, rather than climatological, work see Masumi Zaiki and Togo Tsukahara. "Meteorology on the Southern Frontier of Japan's Empire: Ogasawara Kazuo at Taihoku Imperial University." *East Asian Science, Technology, and Society*, Vol. 1 No. 2 (2007). 183-203. More work has been done on China. See particularly P. Kevin MacKeown. *Early China Coast Meteorology: The Role of Hong Kong* (Hong Kong: Hong Kong UP, 2011).

Before the 19th century, meteorological forecasting was both qualitative and highly localized. The use of the barometer and thermometer since the 17th century had generated increasingly precise *descriptions* of the weather, but computational algorithms through which the present state of the atmosphere could be calculated to predict future states would not become operational until after World War II.[209] Likewise, the relatively slow pace by which information could travel from one observation station to another constricted the degree to which weather could be understood as a *synoptic* phenomenon. Synoptic is a technical term which measures atmospheric phenomena on the scale of 1,000 kilometers or more.[210] It is only at this large scale that some of the fundamental objects of meteorological interest, such as air masses and weather fronts, become visible.[211]

Here I use "synopticism" to describe a certain epistemic framework through which modern meteorology evolved, one in which experts came to envision weather as a phenomenon whose future state could only be predicted given a data set over a large area. While the scale of prediction grew generally over time, the invention of the telegraph in the mid-19th century marked a decisive break between the ways in which meteorologists could understand weather phenomena and the way in which laypeople, depending on their local observations, could do so. With the telegraph, information could be shared rapidly enough to generate nearly synchronous knowledge of weather behavior at different points within a large area.

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[209] H. Howard Frisinger. *The History of Meteorology: to 180*0. First published in 1977 (Boston: American Meteorological Society, 1983). 47-79; Frederik Nebeker. *Calculating the Weather: Meteorology in the 20th Century* (San Diego: Academic Press, 1995). 11-12, 41.

[210] "Cyclonic Scale." *Meteorological Glossary*. American Meterological Society. Last modified 25 April 2012. http://glossary.ametsoc.org/wiki/Cyclonic_scale.

[211] For the discovery of air mass behavior, see Nebeker. *Calculating the Weather*, 84-85; Mark Monmonier. *Air Apparent: How Meteorologists Learned to Map, Predict, and Dramatize Weather* (Chicago: Chicago UP). 57-66.

Weather prediction has always been a part of human societies around the world, and the association of expertise with foreknowledge of the weather is not a purely modern artifact. After all, the detailed astrological and astronomical analyses that have been used to forecast meteorological behavior were the province of those with training in these sorts of observations. However, whether it was expert analysis or that done by those who were deeply invested in the future weather, like farmers and sailors, forecasting necessarily could only draw on locally available data.[212] In 19th century England, the local "weather wisdom" of those who supposedly had greater physical connection to the elements was seen as both a privileged insight and a form of knowledge that could not be standardized in scientific language.[213] These were embodied mechanisms of prediction, what Katharine Anderson refers to as "flesh-barometers."[214]

The "weather signs" that farmers and sailors relied upon drew upon their sensory experience of the material environment and memories of that environment's patterns. Predictions took the form of associations between various events, such as animal behavior, astronomical appearances, or cloud movements and shapes, and practically significant weather "outputs" like heavy rain or cold temperatures.[215] The validity and scientific importance of local or indigenous weather knowledge, a much discussed topic in anthropological literature, will not be touched on here.[216] Needless to say, the form that these "grounded" forms of knowledge took was largely

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[212] Frisinger. *The History of Meteorology*, 1-12; For non-Western summaries, see MacKeown. *Early China Coast Meteorology*, 2-5; For China, India, and the Islamic World, see the relevant entries in the *Encylopaedia of the History of Science, Technology, and Medicine in Non-Western Cultures*. Ed. Helaine Selin (Springer: Amsterdam, 2008). 1662-1668. Japan will be discussed in detail shortly. See also James Rodger Fleming. *Meteorology in America, 1800-1870* (Baltimore: John Hopkins UP, 1988). 1-22.

[213] Katharine Anderson. *Predicting the Weather: Victorians and the Science of Meteorology* (Chicago: Chicago UP, 2005). 175-187.

[214] Ibid, 177. She borrows this phrase from Thomas Hardy's *Tess of the D'Ubervilles*.

[215] Ibid. 175-187.

[216] See recently Douglas Nakashima et al (ed.). *Indigenous Knowledge for Climate Change Assessment and Adaptation* (New York: Cambridge UP, 2018).

qualitative and limited to phenomena that could be encountered through one's body or in the form of learned "weather lore" gained from lived experience and passed down generationally.

While the meteorological instrumentation and observational mechanisms of Japan prior to the late 19th century have largely been unstudied by historians, some degree of knowledge has come in recent years from the work of historical climatologists. These researchers have worked to reconstruct Japan's premodern climate on the basis of patchy and scattered observations which took place in the 18th and 19th century. Many Japanese noble families and religious institutions kept weather diaries during the Tokugawa period which contained qualitative descriptions of local conditions. These writings signified weather states with simple phrases like "rainy" or "fine," or occasionally more precise observations: "fine weather during the day, cloudy in the evening and began to rain in the night." The wide distribution of such weather diaries, juxtaposed with the more precise instrumental data occasionally produced by visiting Western scientists, have been of great value.[217]

However, in more recent years, researchers have uncovered a richer history of premodern instrumental observations done by Japanese as well. Barometers likely imported from England via the Dutch made their way to Japan by the early 19th century, where they would be utilized and continually repaired. From 1825 onward, regular quantitative air pressure measurements were taken by Japanese in Edo.[218] There is little suggestion that these descriptive capabilities

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[217] Takehiko Mikami. "Climate Reconstruction in Historical Times Based on Weather Records." *Geographical Review of Japan.* Series B, Vol. 61 No. 1 (1988). 14-15; "Climatic Variations in Japan Reconstructed from Historical Documents." *Weather*, Vol. 63 No. 7 (2008) 191-192; A.P.M Baede and G.P. Konnen. "Extracted Weather Data of Nagasaki (Japan) from the Diaries of the Dejima Chief 1700-1860, 1817-1823 and from the Von Siebold Documents 1825-1828: Project Description and File Descriptions." Royal Netherlands Meteorological Institute. Technical Report (2016).

[218] Masumi Zaiki et al. "Recovery of Nineteenth Century Tokyo/Osaka Meteorological Data in Japan." *International Journal of Climatology*, Vol. 26 (2006). 400-404. For more historical context, see Togo Tsukahara. "Reconstructing the Climate of Nineteenth-Century East Asia from the Perspective of the History of Science." *From Beaufort to Bjerknes and Beyond: Critical Perspectives on Observing, Analyzing, and Predicting Weather and Climate, A Collection of Nineteen Essays Evolving from a Conference of the International Commission on History of*

were used to advance predictive capacities, and, prior to the late 19th century, there was certainly no centralized forecasting infrastructure; any predictions were localized and based on sensory phenomena and lore.[219]

However, this was largely the state of weather forecasting in Europe and America as well. While technological capacities in the West had advanced slightly beyond Japan after 1825, the technical gap was much smaller than traditional stereotypes of a "closed" Japan suggest. When access to modern meteorology expanded in the late 19th century, Japanese researchers were already primed to make use of the synoptic methods generated by the weather map in the same way that Western scientists were prior to the invention of telegraphic forecasting. In weather forecasting, modernity in the 19th century in the West and in Japan was separated not by a fundamental cultural rift expanding over centuries, but by a mere few decades.

It was the material power of electrical telegraphy, technology wherein copper wires facilitated the transfer of signals via electricity over a distance, which allowed meteorology to suddenly begin to lurch into modernity. The chemical composition of copper atoms, which gave them this hyper-conductivity, made way for this shift.[220] In 1844, Samuel Morse and Alfred Vail first demonstrated the efficacy of long-range communication by way of electrical telegraph with the creation of a direct Washington-Baltimore line. The first transmission memorably quoted from the *Book of Numbers*: "What hath God wrought."[221]

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*Meteorology (ICHM) Held in the Baroque Library of Kloster Polling, Germany, July 5-10, 2004*. Ed. Stefan Emeis and Cornelia Ludecke (Augsburg: Verlag, 2005). 117-128. On a very different note, historian of science Yulia Frumer has written about the translation and cognition of meterological concepts in Japan that accompanied the import of instruments like the barometer. Yulia Frumer. "Translating Words, Building Worlds: Meteorology in Japanese, Dutch, and Chinese." *Isis*, Vol. 109 No. 2 (2018). 326-332.

[219] For an interesting popular description of some practices, see Aaron Perry. "Yononakazakura: Japan's Ancient Almanac." *Taiken Japan*. 20 May 2016. https://taiken.co/single/yononakazakura-japans-ancient-almanac/.

[220] See LeCain on copper: *The Matter of History*, 244-305

[221] Samuel Morse. "'What Hath God Wrought' Telegraph Message." 1844. *The National Museum of American History*. http://americanhistory.si.edu/collections/search/object/nmah_713485.

Only two years later, William Redfield proposed the use of telegraphs, "which will probably soon extend from Maine to the Mississippi," to predict and warn of weather events. By the 1850s, the telegraph was in use for this purpose in both America and Britain. Prior to the telegraph, gathering weather information from various locales required at least a day by train, as shown by the earliest daily weather reports synthesized in London by James Glaisher. Earlier, Benjamin Franklin had used word of mouth and news reports to reconstruct synoptic weather behavior from recent days or weeks.[222] Absent the near-instantaneous transmission of information across a large area, forecasters could not accurately predict particular local weather patterns through the knowledge of general synoptic weather behavior.

Electric telegraphy made possible the synoptic weather map. Essentially, what God had wrought was the collapse of miles into inches. The weather map allowed forecasters to visualize weather on a large scale, seeing how a collection of local air moistures, wind speeds, and atmospheric pressures could build up to reveal reliably patterned behavior that could be tracked: "Its [the synoptic method's] premise was that knowledge of the present over a broad area can yield foreknowledge of the weather at points within that area."[223] These maps tracked weather characteristics measurable at individual locales and depicted these measurements on a two-dimensional surface juxtaposed with the physical geography of the area. With the weather map, the meteorologist could see the combination of seemingly discreet observations taking place at the same time and find the common pattern, "discovering natural order in a clutter of details."[224] By the late 19th century, measurers across the country used standardized instruments to report

[222] Fleming. *Meteorology in America*, 141; Nebeker. *Calculating the Weather*, 36; Monmonier. *Air Apparent*, 39.
[223] Nebeker. *Calculating the Weather*, 36.
[224] Katharine Anderson. "Mapping Meteorology." *Intimate Universality: Local and Global Themes in the History of Weather and Climate*. Ed. James Rodger Fleming et al (Sagamore Beach: Watson Publishing International, 2006). 70-72.

their readings to the central office where groups of clerks would draw the corresponding images and values.[225]

Katharine Anderson thus argues that the synoptic method allowed meteorologists to effectively synthesize the patches of local knowledge so sought after into a more standardized general description. While local grounded weather wisdom was incorporated into modern meteorology, "telegraphy thus symbolically extended the sensibilities of the central office and so offered a way for the modern scientific investigator to compete with the experience of local experts."[226] However, we should not imagine that this "absorption" of local knowledge did not entail epistemic breaks. In exactly this act of compilation, weather forecasters began to understand weather in ways that embodied local experts could not; much more than a symbolic extension was taking place.

One of the pillars of LeCain's neo-materialist synthesis discussed earlier is Andy Clark's work in cognitive philosophy. In their classic paper from 1998, "The Extended Mind," Clark and David Chalmers argue that the brain, perhaps as an evolutionary mechanism, has come to rely on the environment surrounding the body in significant ways. People's brains and objects around them often form "coupled" cognitive systems in which "epistemic credit" is distributed between them. To modify the famous phrase from Claude Levi-Strauss, our environments are "good to think with."[227] Our minds and our beliefs are coupled systems of these sorts, and we use the objects around us as epistemic tools all the time in ways that spread cognitive burdens to our

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[225] Monmonier. *Air Apparent*, 7-9.
[226] Anderson. *Predicting the Weather*, 185-188.
[227] The original quote, usually paraphrased as "Animals are good to think with," appears in Claude Levi-Strauss. *Totemism*. First published in French in 1962. Trans. Rodney Needham (Boston: Beacon Press, 1963). 89: "The animals in totemism cease to be solely or principally creatures which are feared, admired, or envied; their perceptible reality permits the embodiment of ideas and relations conceived by speculative thought on the basis of observations. We can understand, too, that natural species are chosen not because they are "good to eat" but because they are "good to think."

environments, such as when we physically rearrange Scrabble tiles to provoke new mental arrangements or keep journals to store our memories. These tools are "in the loop," rather than "dangling at the end of a long causal chain" resulting from internal cognizing.[228]

Weather maps are in fact exemplars of this phenomenon. It is tempting to think of the weather map as a *product* of mental and physical labor, one that represents cognitive processes after they have been completed. In reality, however, these maps were significant *constituent* parts of cognitive processes distributed between meteorologists and the maps they used. People did not think *up* maps to represent their conclusions, they thought *with* maps to come to those conclusions in the first place. Regarding his prototypical 1686 map of the trade winds, Edmund Halley wrote that "'tis possible the thing may be better understood [using the visuality of the map], than by any verbal description whatsoever."[229] In the same vein, Alexander von Humboldt wrote of his temperature maps that they "speak to the senses without fatiguing the mind,"[230] an explicit suggestion in line with Clark's understanding of cognitive offloading.

Meteorologists could gain "meaning at a glance," as well as the tools to "entirely alter the attitude of mind with which we [meteorologists] regard weather changes."[231] Because telegraphs collected data from a large range of locales, the extended mind thesis allows us to understand that the coupled cognitive systems of man and map allowed forecasters to extend their epistemic abilities through the map, and the telegraphy that produced it, across a synoptic region of space. The map allowed them to immediately know the weather as a large-scale patterned phenomenon in ways that locals could not. In integrating vast amounts of local knowledge into readily usable

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[228] Andy Clark and David Chalmers. "The Extended Mind." *Analysis*, Vol. 58 No. 1 (1998); See also LeCain. *The Matter of History*, 6, 112-114.
[229] Nebeker. *Calculating the Weather*, 16-17.
[230] Anderson. *Intimate Universality*, 70
[231] From English meteorologist Ralph Abercromby, quoted in Anderson. *Intimate Universality*, 72.

objects, the nature of forecasters' knowledge became very different from laypeople who relied on their senses but could not extend their cognition of instantaneous events very far from their bodies.

As cartographic meteorology advanced toward the end of the 19th century, maps not only collapsed space, but time as well, making days visible "at a glance." By binding books made up of successive days' maps on translucent paper, the motion of a storm system, say, was readily apparent.[232] Pages of measurements which one's embodied mental abilities could not cope with could be made manifest. In fact, the influence of the maps was such that some argued for so-called "weather typing." In theory, forecasting could be accomplished simply by looking at one day's map and comparing to a similar map and its successors from the cartographic record, usefully stored in bulk outside of the forecaster's limited skull.[233] More recently, one group of researchers describe how forecasting expertise is "not all just in the head" as contemporary meteorologists keep "treasure maps" of old forecasts, charts, images, and other records from the past. They refer to these as "external memories" which serve as a crutch, allowing forecasters to unburden their headspace, distributing their cognition amongst their filing cabinets.[234]

The weather map, and the telegraphic technology which underwrote it, served as an epistemic springboard through which meteorologists began to think synoptically, a framework unavailable to the localized perceptions of laypeople. It was this novel epistemic equipment that would be transferred to Japan in the late 19th century. While Japanese meteorology was not as far behind Western methods and instruments as one may expect, the Meiji modernization after 1867 entailed significant changes. In 1875, the Tokyo Meteorological Observatory was founded.

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[232] Monmonier. *Air Apparent*, 50-51.
[233] Ibid, 15-17. Nebeker. *Calculating the Weather*, 43-44.
[234] Robert R. Hoffman et al. *Minding the Weather: How Expert Forecasters Think* (Cambridge: MIT Press, 2017). 208.

Japanese scientists collaborated significantly with Western experts to advance its meteorological programs.[235] Thomas C. Mendenhall, a physics professor from Ohio, was one such expatriate, who lived in Japan for three years teaching at the newly founded Tokyo Imperial University. While in Tokyo, Mendenhall would help lead meteorological advances.[236]

Mendenhall himself apparently had little interest in his meteorological activities in hindsight; in his *Autobiographical Notes*, they occupy a sparse couple of sentences.[237] However, his 1880 *Report on the Meteorology of Tokyo* speaks to the modern shifts Japanese meteorology was soon to undergo. Mendenhall documents a series of local observations of air pressure, wind speed, humidity, rainfall, and temperature. While Mendenhall worried about the state of Japanese instruments, he optimistically noted that "it is now proposed, however, to equip the observatory with an entirely new and complete set of apparatus, such as in use in the first class stations of the Signal Service of the United States."[238] State of the art instrumentation was not such a fundamental problem for modernizing Japanese meteorology, as Mendenhall's remarks point to the rapid pace at which such technology could be modernized.

More interesting in Mendenhall's account is his analysis of a typhoon that October. He notes that, even with the substandard instruments, his team was "able to trace, with tolerable

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[235] For an overview of this modernization, see MacKeown. *Early China Coast Meteorology*, 21-22; Mitsuhiko Hatori et al. *Modernization of Meteorological Services in Japan and Lessons for Developing Countries*. Japan Meteorological Business Support Center (2015). 9-10. For more popular accounts, see "Come Rain Come Shine: The Weather in Japan." *Nippon.com*. 24 June 2014. https://www.nippon.com/en/genre/society/l00060/; Mark Brazil. "Seasons Come and Go — but When?" *Japan Times*. 11 January 2014. https://www.japantimes.co.jp/life/2014/01/11/environment/seasons-come-and-go-but-when/#.W99boOJRfIU.

[236] See MacKeown, 21-22; George Iles. "Sketch of Thomas Corwin Mendenhall." *Popular Science Monthly*, Vol. 37 (1890).

[237] Richard Rubinger (ed.). *An American Scientist in Early Meiji Japan: The Autobiographical Notes of Thomas C. Mendenhall* (Honolulu: Hawaii UP, 1989). 40. Mendenhall's journals, both in Japan and before and after, can also be found in Sybil Drew. *Self-Styled Genius: The Life of Thomas Corwin Mendenhall* (Jan and Brooklyn, 2016).

[238] T.C. Mendenhall. *Report on the Meteorology of Tokyo for the Year 2540 (1880)* (Tokyo: Tokyo Daigaku, 1881). 1.

completeness, the most important elements of the phenomenon." Rather than instrumentation, the more fundamental issue at hand was scale:

> The storm was by no means local… In order to undertake anything like a complete description of the phenomenon, it would be necessary to collect from numerous and widely distributed sources all of the facts possible concerning its rise and progress.[239]

Later, Mendenhall foreshadowed the developments that would allow forecasters to escape these embodied mental constraints: "had an efficient system of observations, telegrams, and signals existed, timely warning might have been given of its approach."[240]

The basis for the shift to a synoptic epistemology in Japan was literally laid down in the decades prior to 1883. After Commodore Perry introduced telegraph technology in 1854, the Japanese government, monopolizing electrical telegraphy, hired British help and began to lay lines in 1869. Yukichi Fukuzawa, in the same book where he denounced the materialistic concerns of the Meiji state, pointed to the telegraph as a powerful symbol of the leaps in knowledge tied to Western civilization:

> If we could bring back the ancient sages to live in our modern world… [and] let them listen to news coming in from thousands of miles away over the telegraph, they would surely be amazed… Even if you let Bodhidharma sit in front of a wall for ninety years, he would never be able to invent the steam engine or the telegraph.[241]

Along with bricks, electrical telegraph technology embodied Japanese modernity, and Fukuzawa both praised these changes and worked to translate the terminology itself into Japanese.[242] The first long-distance line was laid between Tokyo and Yokohama in 1869, and in 1878, telegraph offices were opened throughout the country while a central Telegraph Office was opened in

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[239] Ibid, 23.
[240] Ibid, 27.
[241] Fukuzawa. *An Outline of a Theory of Civilization*, 110-118.
[242] See Eiichi Itoh. "The Danish Monopoly on Telegraph in Japan: A Case Study of an Unequal Communication System in the Far East." *Keio Communication Review*, No. 29 (2007). 85-86. Fukuzawa translated "telegraph" literally as "transported message" or *denshin*.

Tokyo itself. By 1883, "telegraph lines were spread almost over the whole country" according to an official history published a decade later.[243]

The centralization of telegraphic communication by the 1880s paved the way for the first weather map in Japan, issued by the Tokyo Meteorological Observatory on March 1st, 1883 (Fig. 2.2). With help from the German mathematician Erwin Knipping, the map was produced under the direction of Surveyor-in-Chief I. Irai. Knipping had come to Japan in 1872 and had produced significant weather observations already.[244] The map is a synoptic portrayal of the whole of the archipelago. Specifically located markings shown on the map display general weather conditions as well as wind direction. English descriptions explain how each kind of circle symbolizes different conditions: filled in circles representing "rain," unfilled "clear," thick borders "cloudy." These descriptions recall the local qualitative descriptions found in Tokugawa-era weather diaries, suggesting Anderson's point that the synoptic method absorbed and synthesized local knowledge.

However, from the map emerge patterns inaccessible to the embodied lay observer. Based on standard notation derived from Western maps, the black lines marked as "low" to the south and "high" to the north are so-called *isobars* that represent barometric measurements of air pressure. The isobars are drawn to pull like measurements together, allowing pressure gradients to visibly emerge as lines drawn over areas with similar pressure. Wind direction measurements also point to a directional movement from northwest to southeast. In short, the collection of data

[243] Shinjiro Mayeda. *Outlines of the History of Telegraphs in Japan* (Tokyo: Tsushinkyoku, 1892). 1-5. This is the most comprehensive account of the early history of electrical telegraphy in Japan I have found. For more specialized studies, see Itoh as well as Jack Nicholls. "The Impact of the Telegraph on Anglo-Japanese Diplomacy during the Nineteenth Century." *New Voices*, Vol. 3 (2009). 1-22.

[244] Hatori et al. *Modernization of Meteorological Services*, 9; Zaiki et al. "Recovery of Nineteenth Century Tokyo/Osaka Meteorological Data in Japan." 404-405; Mackeown. *Early China Coast Meteorology*, 21-22.

made possible by the telegraphs did not just create a set of individual points, but was a synergistic process that made visible broader patterns.

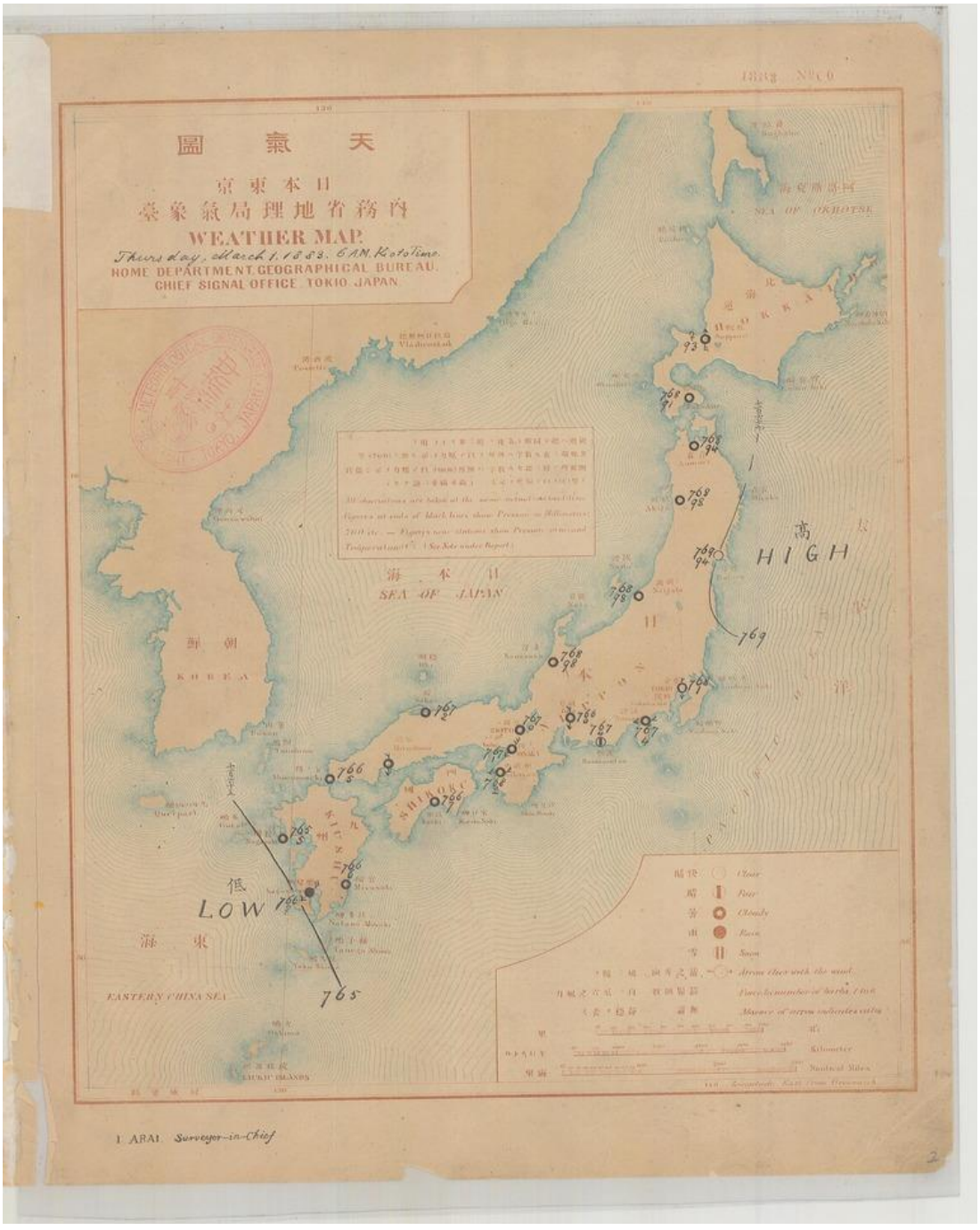


Figure 2.2[245]

[245] *Nihon de Saisho no Tenkihaifu* ("Japan's First Weather Map") "Notable Weather Charts in the Past." *Digital Typhoon: Database of Weather Charts for Hundred Years – Archive of Weather Charts in the Past and the History of Japanese Meteorological Observations*. 1 March 1883. http://agora.ex.nii.ac.jp/digital-typhoon/contribution/weather-chart/001.html.ja.

After 1883, the Observatory, renamed the Central Meteorological Observatory in 1887, produced thrice-daily maps to track weather movement across the archipelago.[246] Only months after the first map, the Observatory issued Japan's first storm warning on May 26th. Based on changes since 10:00 PM the night before, the observatory declared "the barometer has fallen much in last eight hours, most over Shikoku and the Inland Sea… Warned[,] the whole coast."[247] The origins of this warning can be seen in the 6:00 AM map produced on that date, where isobars mark out a cyclonic low-pressure system in the southwest. By 2:00 PM, forecasters had charted the storm's eastward movement over Honshu (Fig. 2.3-2.4). The map's ability to collapse space and time, as explained earlier, allowed Japanese forecasters to step into meteorological modernity and produce the first official national storm alert in Japanese history. This warning was only possible after 1869 because it required a synoptic knowledge of surface weather conditions across Japan so as to create visually striking patterns of wind movement and air pressure. The local observer, situated in Tokyo, could not know the weather in this way: the first step in modernizing meteorological forecasting was getting outside one's own head.

[246] Michael Grossman and Masumi Zaiki. "Reconstructing Typhoons in Japan in the 1880s from Documentary Records." *Weather,* Vol. 64 No. 12 (2009). 316.
[247] Hatori et al. *Modernization of Meteorological Services,* 9.

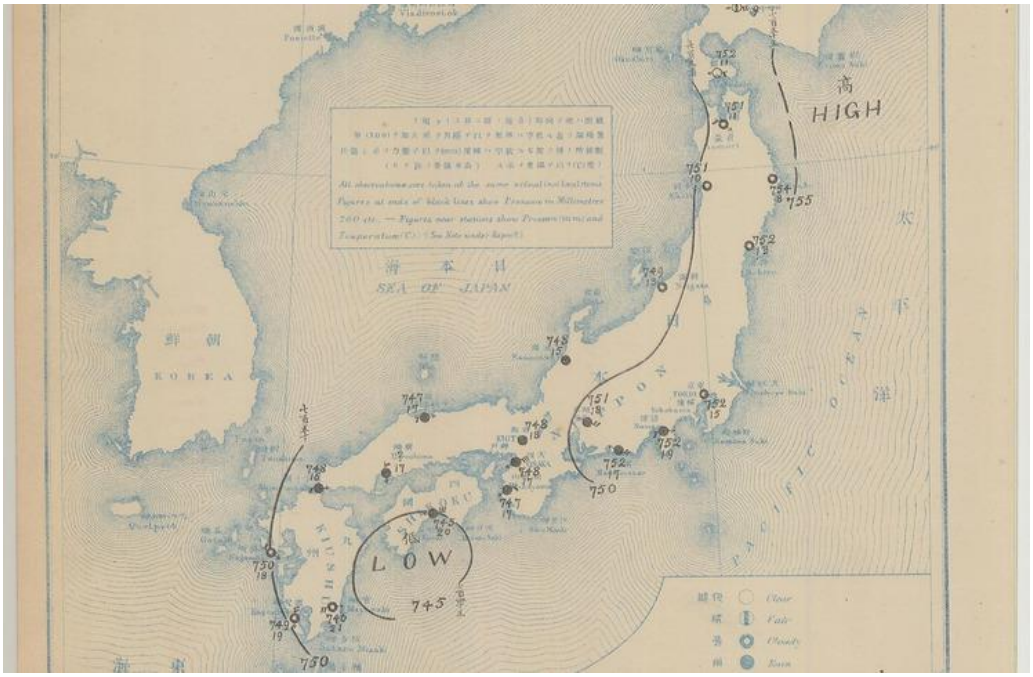


Figure 2.3

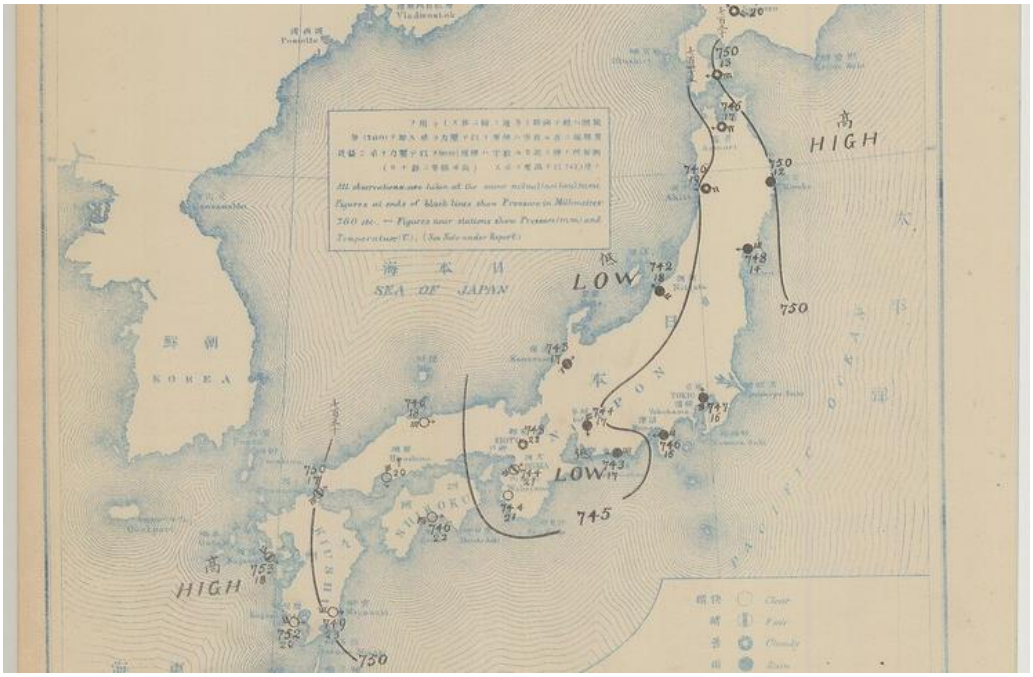


Figure 2.4[248]

[248] *Nihonhatsu no Bouhoukeihou* ("Japan's First Storm Warning"). "Notable Weather Charts in the Past." *Digital Typhoon: Database of Weather Charts for Hundred Years – Archive of Weather Charts in the Past and the History of Japanese Meteorological Observations*. 26 May 1883. http://agora.ex.nii.ac.jp/cgi-bin/weather-chart/search_day.pl?type=as&year=1883&month=05&day=26&lang=ja.

**Numerical Weather Prediction**

In his 1837 *Lectures on the Philosophy of History*, Hegel famously wrote that "history goes from East to West."[249] Theories of modernity for a long time were essentially the inverse of this pattern, as modernity was supposed to have diffused from its teleological endpoint in Western civilization back to the East. In Chapter 1, I did not entirely disown this narrative, against the grain of what most historians now believe, because I believed it essential to understand that Japan really did modernize in some ways via the relatively *straightforward* diffusion of technology and architecture that evolved in European countries since the 17th century during the Great Rebuilding. However, not long after 1868, many modernizing trends defy such a narrative. Scientific disciplines that were emerging only in the late 19th century, such as meteorology, are an example of such trends, partially because they were novel and controversial even in the West.

Forecasting by *synoptic meteorology*, i.e. the use of weather maps, was by no means accepted practice at the time. Robert Fitzroy, who made some of the earliest forecasts as the first director of the British Meteorological Office, faced immense tides of criticism from fellow scientists. Many at the time believed that attempting to forecast the future was mere hubris, and that doing so subjectively through the weather map was unscientific. This vicious ridicule played some part in his suicide in 1865, after which the Royal Society stopped forecasting until 1879. The US Weather Bureau was not created until 1870 and did not become a civilian, rather than military, organization until 1890. Sweden, which would become a pioneering country in numerical weather forecasting in the 1950s, did not adopt synoptic meteorological forecasts until

[249] "World History goes from East to West: as Asia is the beginning of world history, so Europe is simply its end." G.W.F. Hegel. *Introduction to the Philosophy of History: with Selections from The Philosophy of Right.* Trans. Leo Rauch (Indianapolis: Hackett, 1988). 92.

1905.[250] When Frederik Nebeker writes that "the synoptic method… was by the end of the 19th century in use throughout Europe and the United States," he homogenizes a set of Western practices and opinions that were diverse and overlooks the *spotty* diffusion of synoptic meteorology, which Japan adopted in the very same period, even before some Western countries.[251]

This spotty spread of synopticism, which represented the first modernizing step in meteorological forecasting, mirrors the diffusive patterns of numerical weather prediction (NWP) in the 1950s. While the weather map had clearly developed in Europe and was largely received in Japan, numerical prediction did not follow this pattern. Between 1950, when Japanese scientists began to write about numerical prediction, and 1960, when the First International Symposium on Numerical Weather Prediction was hosted in Tokyo, Japanese researchers at the University of Tokyo made seminal contributions to the field. Unlike telegraphic forecasting, Japan came onto this stage of modernity *on the ground floor*, as it were. While older historiography underestimated the degree of instrumental observations in premodern Japan, the general historiography on NWP tends to ignore or minimize the Japanese contribution, localizing its history mostly to the United States and Scandinavia. This section has two goals: (1) to continue to show how meteorology was modernized prior to the introduction of satellites in the 1960s, and (2) to write a transnational history of NWP, focusing on the ways Japan reacted and contributed to this modernity.

The prehistory of NWP can most usefully be traced back to the formulation, in 1904, of the so-called *primitive equations*. After the advent of synoptic methods, scientists were frustrated by the lack of vigor in forecasting, a practice which relied more on experience of map-reading

[250] Nebeker. *Calculating the Weather*, 39;
[251] Nebeker. *Calculating the Weather*, 38.

and subjective expertise than it did on the application of physical principles of atmospheric change. Vilhelm Bjernkes, whose Bergen School in Norway would later introduce the fundamental concepts of air masses and fronts, sought to provide a provide a more rigorous form of forecasting based on a set of primitive equations which could represent atmospheric motion as an expression of fundamental laws of Newtonian mechanics, ideal gases, thermodynamics, and more. Bjerknes essentially synthesized the advances made in physics since the 17th century.[252]

The advent of the primitive equations rightfully marks the beginning of NWP, at least in theory. Both in the West and in Japan, instruments like barometers had used numbers to represent observations of pressure, temperature, and the like. However, before Bjerknes, forecasters did not plug numerical observations into equations to give the future state of the atmosphere. With the primitive equations, mathematics could not only represent the present state of weather phenomena; it could represent the active forces that pushed the atmosphere around. Theoretically, given an accurate numerical account of the present state, the future state could be revealed based on deterministic laws represented by the primitive equations.

The first attempt, however, to put the primitive equations to work was a massive practical failure. In his groundbreaking *Weather Prediction by Numerical Process* (1922), Lewis Fry Richardson used seven primitive equations to model past weather changes over a six-hour span based on an initial state. The computation took six weeks to complete, and dramatically missed the mark.[253] As another meteorologist put it at the time, "the wildest guess… would not have

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[252] See Nebeker. *Calculating the Weather*, 49-52; For more on Bjerknes, see Robert Mark Friedman. *Appropriating the Weather: Vilhelm Bjerknes and the Construction of a Modern Meteorology* (Ithaca: Cornell UP, 1989). For the importance of the Bergen School in establishing air mass analysis based on the front concept (an innovation whose adoption was delayed in the United States for decades), see Nebeker. *Calculating the Weather*, 84-85; Gisela Kutzbach. *The Thermal Theory of Cyclones: A History of Meteorological Thought in the Nineteenth Century* (Boston: American Meteorological Society, 1979). 207-220.

[253] See Nebeker. *Calculating the Weather*, 58-81; Kristine C. Harper. *Weather by the Numbers: The Genesis of Modern Meteorology* (Cambridge: MIT Press, 2008). 100. For a more recent edition of Richardson's own classic work, see Lewis Fry Richardson. *Weather Prediction by Numerical Process*. 2nd Edition. First published in 1922

been wider of the mark."[254] While Richardson's failure served as a deterrent for decades to those hoping for a numerical prediction scheme, his error was more practical then fundamental, and his work would become a landmark for those who successfully operationalized numerical prediction in the 1950s. First, the primitive equations themselves were not usable in their basic form (at least until computational ability had vastly increased); they needed simplification. Second, the ability to rapidly process the calculations themselves needed enhancement. The first problem, a theoretical issue, Jule Charney, as discussed below, would address in the late 1940s, while the second, a question of technology, would await the invention of the computer. Both of these problems were in fact solved within a narrow span of years during the Meteorology Project, the cradle of NWP, within the Institute for Advanced Study (IAS) at Princeton from 1947 to 1953.

The Meteorology Project began after World War II through the coordinated efforts of a number of mathematicians, scientists, and forecasters. In her history of the Project, Kristine Harper emphasizes that many accounts, including Nebeker's, minimize the role played by meteorologists and Scandinavians. To be sure, at the forefront of the Project was the American mathematician John Von Neumann, whose work was famously fundamental to the development of computing, game theory, and quantum mechanics. The basic narrative that Harper challenges is that the Project arose through Neumann's mostly unilateral efforts to put his new computer to the test, seeing weather prediction as a perfect problem to work with. Rather, Harper emphasizes the role of meteorologists, especially of Carl-Gustav Rossby, in organizing the Project and using Von Neumann's nascent interest in meteorology to take advantage of his mathematical and technical prowess as well as his financial and academic resources.

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(Cambridge: Cambridge UP, 2007). For more on Richardson and his influence, see Peter Lynch. *The Emergence of Numerical Weather Prediction: Richardson's Dream* (Cambridge: Cambridge UP, 2006).

[254] Quoted from Napier Shaw in Nebeker. *Calculating the Weather*, 76.

Regardless of how credit should be distributed between different individuals and fields, the general narrative of the Meteorology Project and early NWP is straightforward enough. After a 1946 meeting headed by Von Neumann, the first major breakthrough came when Jule Charney joined the team in 1948. In a series of papers in 1949, Charney created simplified, "filtered" versions of the primitive equations, reducing the variables and small-scale "noise" to produce a workable set of formulae that could adequately forecast large-scale, stable phenomena.

This model was first put to the test in 1950, when the Project team traveled to Maryland to use the ENIAC (Electronic Numerical Integrator and Computer), one of the earliest computers, to complete the first numerical forecasts. After publishing their results in the same year, the team continued to work until 1955 using more advanced computers and more complex models. These earliest trials were theoretical tests of the models and computers, but in 1953 and 1954, the Institute of Meteorology in Stockholm produced the first real-time numerical forecasts using computers. In 1955, the Joint NWP Unit (JNWPU) in the United States began making real-time, daily forecasts based on numerical prediction. In the following years, NWP operations spread over the world, including Japan, and became firmly established in the mainstream by the 1960s.[255]

Unmentioned in this narrative is that as early as 1950, Japanese students and professors at the Geophysics Institute of Tokyo University became involved in NWP research. This group of researchers would both lead the Japanese meteorological community onto the stage of NWP,

[255] See Nebeker. *Calculating the Weather*, 134-172; Harper. *Weather by the Numbers*, 91-239; A. Wiin Nielsen. "The Birth of Numerical Weather Prediction." *Tellus A: Dynamic Meteorology and Oceanography*, Vol. 43 No. 4 (1991). 36-52. For the original influential papers mentioned, see Jule Charney. "On a Physical Basis for Numerical Prediction of Large-Scale Motions in the Atmosphere." *Journal of Meteorology*, Vol. 6 (1949). 371-385; Jule Charney and Arnt Eliassen. "A Numerical Method for Predicting Perturbations of the Middle Latitude Westerlies." *Tellus*, Vol. 1 Issue 2 (1949). 38-54; Jule Charney, Ragnar Fjortoft, and John Von Neumann. "Numerical Integration of the Barotropic Vorticity Equation." *Tellus*, Vol. 2 No. 4 (1950). 248-257. As will be seen, Charney's model developed in 1949 would the primary center around which Japanese meteorologists formulated their research in the early 1950s.

and, more importantly, play a significant role in the development of NWP from the beginning. Even before 1950, this group was excited by Charney's 1947 published dissertation, which became available in US occupied Japan in 1949. As one student recalled: "Professor Syono [the chair of the Department of Meteorology], rushed into our classroom… and [holding Charney's paper] excitedly proclaimed 'Look! This paper has modernized the science of meteorology!'"[256]

Shigekata Syono was an established figure in theoretical, or dynamic, meteorology in Japan when Charney's landmark paper appeared. In fact, he was so excited by Charney's research in part because it followed a train of thought he himself had been pursuing in the previous decades with his series of "Studies on Atmospheric Disturbance," for which he was awarded the Japan Academy Prize in 1950.[257] Like Fukuzawa Yukichi, who himself had presided over the Academy in 1879, Syono was an ardent advocate for Japan seeking knowledge in the West and building international research networks.[258] Charney and Syono's convergent research programs in the 1940s laid some of the groundwork for the development of NWP in the United States and Japan in the following years. It was in his dissertation that Charney had introduced the notion that the primitive equations needed to be systemically simplified to reduce the noise that including certain variables produced if one was to correctly describe patterns in cyclone formation. As he wrote, "by eliminating from consideration at the outset the

[256] Akira Kasahara, quoted in John M. Lewis. "Meteorologists from the University of Tokyo: Their Exodus to the United States Following World War II." *Bulletin of the American Meteorological Society*, Vol. 74 No. 7 (1993). 1355. Kasahara is quoted from Lewis' own personal correspondence in 1992.
[257] Ibid. The same anecdote is given in Anders Persson. "Early Operational Numerical Weather Prediction Outside the USA: an Historical Introduction: Part II: Twenty Countries Around the World." *Meteorological Applications*, Vol. 12 Issue 3 (2005). 270. For a list of Prize winners, see "The Imperial Prize, Japan Academy Prize, Duke of Edinburgh Prize Recipients." Activities. *The Japan Academy*. http://japan-acad.go.jp/en/activities/jyusho/031to040.html.
[258] "Past and Present Presidents." About. *The Japan Academy*. http://japan-acad.go.jp/en/about/successive.html. Syono's cosmopolitanism was recalled by his student Kenzaburo Gambo in 1992 (Lewis. "Meteorologists from the University of Tokyo," 1355).

meteorologically unimportant… the perturbation equations are reduced to a system whose solution is readily obtained."[259]

Kanzaburo Gambo, Syono's student who worked as a research associate for the Geophysics Institute, was also greatly impressed with Charney's work. The following year, in 1950, Gambo published a response to it, "The Criteria for Stability of the Westerlies," in which he tweaked and simplified Charney's math. Gambo then began a correspondence with Charney in Princeton and sent along his paper. Apparently, given that Charney would cite Gambo's commentary and implement his modifications more than a decade later, Japanese meteorologists were already making lasting contributions to NWP in 1950, prior even to the first ENIAC forecast later that year.[260] Gambo was even invited to take part in the Meteorology Project at the IAS, where he worked for a little more than a year between 1952 and 1954. During this time, Gambo not only contributed to the work of the Project, but sent excited reports back to the Geophysical Institute in Tokyo describing its progress and methods.[261]

In her history of the Project, Harper does briefly mention Gambo's presence, noting the increase in staff during 1953 as well as (in parentheses) the Japanese Meteorological Agency's plan to start its own NWP operations.[262] However, she does not explore the context and conceptual significance of this development. Japan had just lost the Pacific war and was under

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[259] Jule Charney. "The Dynamics of Long Waves in a Baroclinic Westerly Current." *Journal of Meteorology*, Vol. 4 No. 5 (1947). 135. For his simplifications of the mathematics, see p. 139-143. For a contextualized explanation of Charney's early work, see Norman A. Phillips. "Jule Charney's Influence on Meteorology." *Bulletin of the American Meteorological Society*, Vol. 63 No. 5 (1982). 493.

[260] See Lewis. "Meteorologists from the University of Tokyo," 1356; Lewis also gives this account in "Sasaki's Pathway to Deterministic Data Assimilation." *Data Assimilation for Atmospheric, Oceanic and Hydrologic Applications*. Ed. Seon K. Park and Liang Xu (Berlin: Springer-Verlag, 2009). 4. Kenzaburo Gambo. "The Criteria for Stability of the Westerlies." *Geophysical Notes* (1950); Jule Charney and Philip Gerald Drazin. "Propagation of Planetary-scale Disturbances from the Lower into the Upper Atmosphere." *Journal of Geophysical Research*, Vol. 66 No. 1 (1961). 91-92.

[261] Lewis. *Data Assimilation*, 4-5.

[262] Harper. *Weather by the Numbers*, 192.

US occupation from 1945 to 1952. When he gained an appointment to the Geophysical Institute in 1947, Japan's socio-economic situation was in dire straits. As another associate, Yoshimitsu Ogura, recalls, he could not find any housing due to the destruction caused by the bombings and merely bought futons and slept in the lab.[263] Moreover, as I will describe in more detail shortly, the Institute lacked the computing technology that the Project team had access to, and had to use substandard tools and innovative techniques to experiment on numerical methods throughout the 1950s.

Even with this radical asymmetry in research capabilities, Gambo's paper and arrival at Princeton marked the beginnings of Japan's contributions to NWP. Also in 1950, Syono, Gambo, and others wrote a series of commentaries "On Numerical Weather Prediction" that modified Charney's 1949 models and compared them to their own.[264] Gambo's correspondence between Princeton and Tokyo catalyzed the development of the NWP Group at the Geophysical Institute, which began in full force when Gambo returned in 1954. It was also in 1954 that the JNWPU was formed in the United States.[265] While the Meteorology Project was the central hub of the development of NWP, the Project itself was a transnational enterprise that did not gradually seep out into the mainstream from America to Europe to Japan. Rather, pockets of modernity spottily emerged around the world in those early years as global networks of intellectual exchange pushed researchers on the outskirts of the Project in the United States and in Japan towards numerical techniques *at the same time*.

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[263] Lewis. "Meteorologists from the University of Tokyo," 1353-1354.

[264] See Persson. "Early Operational Numerical Weather Prediction." 270; Shigekata Syono et al. "On Numerical Weather Prediction (I)." *Journal of Japanese Meteorology*, Vol. 28 Issue 3 (1950). 77-99. Parts two and three both appeared in the journal in 1952, but part one contains the most fundamental work.

[265] See Lewis. "Meteorologists from the University of Tokyo," 1356; Persson. "Early Operational Numerical Weather Prediction," 270; Nebeker. *Calculating the Weather*, 156.

Lacking government funding, the NWP Group in Japan relied on funding from the Asahi Newspaper, which contributed the equivalent of $2,800 for their efforts.[266] By 1960, a strong research tradition had evolved within the NWP Group, which included Syono and Gambo as well as other researchers such as Yoshikazu Sasaki, Akio Arakawa, Michio Yanai, and Tetsuya Fujita. Many of them made important contributions during this vital period in the 1950s; others began research programs that would become vital components of NWP later; some even became nearly household names in United States (the so-called Fujita scale measure of tornado intensity is familiar to many). Browsing through the *Journal of Japanese Meteorology*, one can see the beginnings of a network of intra- and inter-national citations accumulating during the decade among members of the NWP Group as they built on each other's work.

As Robert Persson and John M. Lewis both point out, the NWP Group made "seminal contributions" during these early stages of NWP.[267] After Gambo returned in 1954, some of the Group followed his lead and emigrated to the United States, attaining research positions at universities or within the US Weather Bureau. Joseph Smagorinsky, a section-chief within the Bureau, recalls the influence these young researchers had. In fact, Smagorinsky had read the work of NWP Group before 1954, but his impression of their capability grew further through his personal connections with them in America. Smagorinsky also makes clear the "two-way avenue" that the emigration created: "I should point out that GFDL [Geophysical Fluid Dynamics Laboratory] itself was young when these scientists joined it… [it] had a strong international flavor, about half its scientists were foreign born. The dedicated work ethic that the Japanese brought with them greatly influenced other GFDL scientists."[268]

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[266] Persson. "Early Operational Numerical Weather Forecasting," 270.
[267] Ibid.
[268] Lewis. "Meteorologists from the University of Tokyo," 1357-1358.

One of those emigres, Yoshikazu Sasaki, had begun to develop his theoretical approach to "objective analysis" prior to leaving Japan. Before prediction could be operational, a "smoothing" process was needed through which, as Sasaki put it, "irregularities, observational errors, and small scale fluctuations which are not of concern" are minimized.[269] Traditionally, this process of "data assimilation," was completed through the subjective judgment of the forecaster. After NWP took off in the 1950s, computer-based objective analysis became possible. Sasaki was especially concerned with making long-range forecasts operational, and saw an answer in a novel application of Hamiltonian mechanics.[270] In papers published in the *Journal of Japanese Meteorology* in 1955 and 1958, Sasaki worked out a method of objective analysis that could be applied to long-range forecasts.[271] As Lewis points out, the computing capabilities of the age constrained the functionality of Sasaki's early work. However, when Sasaki returned to this problem in the 1970s, computing had advanced enough such that Sasaki's methodology, born originally out of his work with the NWP Group, became a powerful tool in numerical forecasting.

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[269] Yoshikazu Sasaki. "An Objective Analysis Based on the Variational Method." *Journal of Japanese Meteorology*, Vol. 36 No. 3 (1958). 77.

[270] The benefits of this approach are based in relatively rarefied mathematical differences based in the way that Langrangian (Hamiltonian) variational calculus differs from Newtonian formalism. For those interested, Lewis writes that "[Sasaki] knew that the governing equations for atmospheric motion stemmed from minimizing the action integral, the time integrated difference between the kinetic and potential energy of the system (the Lagrangian). Now, instead of minimizing the Lagrangian, he could minimize the squared discrepancies between the desired fields (the final analyses of wind and geopotential) and the observations. Instead of integrating over time, integration over space was appropriate in this case" (*Data Assimilation*, 8). More generally, Newtonian mechanics essentially relies on a "particle-by-particle description" of a system, whereas the "variational strategy" of Lagrangian mechanics is based on the difference between the kinetic and potential energy "characteristic of the system as a whole and does not depend on the details of how the system is specified. So we are free to choose ways of describing the system that are easy to work with; we are liberated from the particle-by-particle description inherent in the Newtonian formulation." Gerald Jay Sussman and Jack Wisdom. *Structure and Interpretation of Classical Mechanics*, 2nd Edition (Cambridge: MIT Press, 2014). 3.

[271] Ibid; Yoshikazu Sasaki. "A Fundamental Study of the Numerical Prediction Based on the Variational Principle." Journal of Japanese Meteorology, Vol. 33 No. 6 (1955). 30-43. For more background and a deeper analysis, see Lewis. *Data Assimilation*, esp. 8-12.

Sasaki's fundamental work on objective analysis grew out of his earlier work on typhoon track forecasting, the most important contribution the NWP Group made in the 1950s. In a landmark paper from 1954, Sasaki and Kikuro Miyakoda used Charney's model to forecast typhoon movements. This was, as numerous authors maintain, the first time that numerical methods had been used to track typhoons or hurricanes. To do so, Sasaki and Miyakoda used a simple *barotropic* model that was developed by Charney in 1949 and used in the 1950 ENIAC experiments.[272]

The controversy surrounding this barotropic model was one of the most important elements in the early stages of NWP, and Japanese researchers were well aware of the problems involved. The barotropic model was the key to Charney's original attempt to tease out a set of filtered equations from Bjerknes and Richardson's primitive ones. In order to clean up the small-scale atmospheric noise, Charney effectively made air pressure the only dependent variable, imagining the atmosphere to be barotropic, meaning that density and temperature were functions only of pressure. The model worked well for predicting large-scale, normal motion over time, but to do so it made the atmosphere appear two-dimensional so that vertical motion involved in the rapid conversion of potential to kinetic energy, so-called *baroclinic* disturbances which are often responsible for cyclone formation, are ignored.[273]

To put it simply, in a follow-up paper Sasaki writes: "the method of 'numerical weather prediction' which has been successful in the prediction of the pressure pattern of the large-scale

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[272] Yoshikazu Sasaki and Kikuro Miyakoda. "Numerical Forecast of the Movement of Cyclone." Journal of Japanese Meteorology, Vol. 32 No. 11-12. (1954). 325-335; Persson. "Early Operational Numerical Weather Prediction," 270; Lewis. "Meteorologists from the University of Tokyo," 1356; *Data Assimilation*, 5-6.

[273] For a good overview, of the barotropic model as well the early history of NWP in general, see Amy Dehan Dalmedico. "History and Epistemology of Models: Meteorology (1946–1963) as a Case Study." *Archive for History of Exact Sciences*, Vol. 55 (2001), esp. 402-406. See also Nebeker. *Calculating the Weather*, 143-144; Harper. *Weather by the Numbers*, 124.

disturbances cannot be applied to the small-scale disturbances such as typhoons or hurricanes."[274] In the early 1950s, Charney and others sought to fix this well-known problem by creating higher-dimensional models that could account for vertical forces. These baroclinic models were used to successfully predict cyclone formation in 1953, and were later adopted by the JNWPU in the US. However, others in the Project felt that adaptations to the barotropic model were preferable. The first real-time forecasts made in Stockholm used the barotropic model in fact, and the JNWPU would later discard the multi-level models in favor of the tried and true barotropic ones. Before advances in the 1960s changed the scene more fundamentally, the barotropic model seemed to be the best method.[275]

In their 1954 papers, Sasaki and others in the NWP Group made similar moves: rather than adopting baroclinic models, barotropic models were instead combined with other numerical representations. In part, Japanese scientists had to adopt this strategy because multi-level models simply required a higher degree of computer technology than was available. Nonetheless, Sasaki and his colleagues combined a formula (from Fujita) that could track the small-scale motion of the vortex with the barotropic model. Learning of these results while in the US, Akira Kasahara, another NWP Group émigré, worked with George Platzman at the University of Chicago to confirm the practical potency of this tracking model, and in 1959, its operational efficacy was shown with experiments at the US Weather Bureau.[276] After Gambo's essential sojourn in the

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[274] Yoshikazu Sasaki. "Barotropic Forecasting for the Displacement of Typhoon." *Journal of Japanese Meteorology*. Vol. 33 No. 1 (1954). 1.

[275] See Nebeker. *Calculating the Weather*, 148-151, 159. For more on the barotropic/baroclinic controversy, see Harper. *Weather by the Numbers*, 130, 162-186, 192-194. For Charney's paper, see "Numerical Prediction of Cyclogenesis." *Geophysics*, Vol. 40 (1954). 99-110. Charney also gives a good summary of the problems with the barotropic model (p. 99-100). For an analysis of the relative strength of barotropic and baroclinic models in the 1950s, see Hugh W. Ellsaesser. "Diagnosis of Early Baroclinic NWP Models." *Journal of Applied Meteorology*, Vol. 7 No. 2 (1968). 153-159.

[276] Akira Kasahara. "The Numerical Prediction of Hurricane Movement with the Barotropic Model." *Journal of Japanese Meteorology*, Vol. 14 No. 5 (1957). 386-402; Lester F. Hubert. "An Operational Test of a Numerical

early 1950s, a decentralized transnational intellectual network had evolved. Hurricane track prediction is an example of the importance of this network to the early history of NWP.

One of the most impressive aspects of these early contributions lies in the substantial technological gap that Japanese had to overcome. Until 1959, the NWP Group had no access to any advanced computer and had to creatively adapt the graphical methods established in 1952 by Ragnar Fjortoft. Iterations of these non-computer-based methods had been used to establish the hurricane forecasting techniques. Additionally, the NWP Group used simple desk calculators and a substandard FACOM 100 computer. Even with more advanced technology, the US Project team experienced many constraints due to mechanical malfunctions and internal memory limitations. However, rather than focusing on these limitations in the 1950s, it is important to see how Japanese researchers desperately sought to find the epistemic tools needed to extend their minds into the environment. Since Richardson's work, it was clear that the embodied brain could not handle the computational demands the NWP required to be feasible. In the way that the computer allowed for a new way of knowing the weather through numerical representation and algorithm, it played a role analogous to that played by the telegraph and weather map in the late 19$^{th}$ century. The story of meterological modernity is as much one of ideas as one of the feedback loops meteorologists worked to create between their heads and the objects in their environment.

The technological limitations in Tokyo were finally overcome in 1959, when the Japan Meteorological Agency acquired a more up-to-date IBM704 that could handle the processing needs to make NWP operational. In doing so, Japan became the *third* country, after the US and Sweden, to achieve operational NWP, using a barotropic model similar to that used in the US;

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Prediction Method for Hurricanes." *Monthly Weather Review*, Vol. 87 No. 6 (1959). 222-229. Kasahara also recalls these developments based on Sasaki and Miyakoda's work in Lewis. *Data Assimilation*, 6.

history was not moving from West to East.[277] In fact, like the synoptic method in the prior century, numerical prediction remained controversial. Harper explains how practical forecasters using NWP could note predictive flaws, which could be fed back into the equations to make them better.[278] It was not simply that NWP absorbed and integrated older epistemologies. Rather, in its ability to integrate such synoptic techniques numerically, NWP created a revolutionary break from older meteorological practice, just as the weather map had done almost a century prior. Practitioners in the US slowly and painfully transitioned to the new system in the 1950s and 1960s. Even after NWP became operational in Japan in 1959, Gambo recalls how "at that time, some forecasters understood our efforts well, while others did not accept our efforts."[279] Japan and the United States were developing along nearly synchronous lines, and throughout the 1950s, there was an evolving pattern of international relationships spiraling out of the Meteorology Project.

The clear climax of the early stages of NWP, both in Japan and globally, came with the First International Symposium on Numerical Weather Prediction which was held in Tokyo in 1960. Syono organized this conference with the aim of showing the world Japan's contributions and putting Tokyo on the map as a central node in NWP research. For Japan and the NWP Group, the Symposium was essential to the development of NWP. The Symposium featured the biggest names in NWP at the time, including Charney, and catalyzed Japanese attempts to learn from these founding figures. It also catalyzed a large and permanent emigration to US

[277] Persson. "Early Operational Numerical Weather Forecasting," 270.
[278] Harper. *Weather by the Numbers*, 229-231.
[279] Persson. "Early Operational Numerical Weather Forecasting," 271.

institutions, where Japanese researchers took their experience in Tokyo and distributed it over the world, contributing in countless ways to the history of modern meteorology.[280]

As the importance of these emigres suggests, the Symposium was not only important to the development of NWP in Japan, but also to its growth as a whole. Given that NWP was still a nascent science, the Tokyo Symposium saw these early figures grappling with what were still fundamental issues that would define the history of modern meteorology. It was at the Symposium that the issue of reintroducing the primitive equations into NWP came to the forefront, in the presentations of both Western and Japanese scientists.[281] During the 1960s, enhanced computational abilities allowed these original Bjerknes/Richardson equations to finally become operational and take the place of Charney's filtered models. As the primitive equations expanded to encompass more and more fundamental physical features, Bjerknes' dream of a complete basic model of atmospheric motion became feasible.

Additionally, the 1960 Symposium saw Edward Lorenz present his earliest results concerning the potential breakdown of long-term prediction.[282] These ideas would become the basis of Lorenz's famous argument that many systems, weather being a prototypical case, were inherently chaotic and subject to tiny differences in the initial conditions that accumulated over time to produce dramatic differences. Long-term prediction based on NWP, therefore, faced a major obstacle in that even the smallest knowledge gaps in the original data could make longer

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[280] The original proceedings of the conference are available in English. See Shigekata Syono (ed.). *Proceedings of the International Symposium on Numerical Weather Prediction in Tokyo, November 7-13, 1960* (Tokyo: The Meteorological Society of Japan, 1962). See also Persson. "Early Operational Numerical Weather Forecasting," 271; Lewis. "Meteorologists from the University of Tokyo," 1356-1357.

[281] See Kanzaburo Gambo. "The Use of the Primitive Equations in Balanced Condition" (p. 121-130); Joseph Smagorinsky. "A Primitive Equation Model Including Condensation Processes" (p. 555-556). See also the panel discussion on "Equations of N.W.P." (p. 649-651). *Proceedings of the International Symposium on Numerical Weather Prediction in Tokyo.* For more on the revival of the primitive equations, see Nebeker. *Calculating the Weather*, 170.

[282] Edward N. Lorenz. "The Statistical Prediction of Solutions of Dynamic Equations." *Proceedings of the International Symposium on Numerical Weather Prediction in Tokyo*. 629-635.

forecasts unfeasible. Later developed into "chaos theory," these insights would become of fundamental importance to the development not only of meteorological practice in the next decades, but also of science and mathematics as a whole. As these examples show, the Symposium was, as Kasahara put it, "one of the epoch-making events in the history of NWP." Tokyo was literally at the center of these developments. It was not only the contributions of Japanese scientists that make Japan so important in the history of modern meteorology, but its place as a locus in the global networks of exchange that the Symposium fostered.[283]

Those individual contributions were, however, also front and center. Specifically, Japanese work on hurricane track prediction, which had been so influential in the United States, assumed a large role in the proceedings. Charney himself presented his own work with one of the founding NWP Group members, Yoshimitsu Ogura. After another Japanese researcher under Syono, Michio Yanai, presented on typhoon formation, Charney himself visited Yanai and Syono at the University of Tokyo to continue the discussion. Yanai's research, presented and discussed at the Symposium, would become increasingly significant during the next decade.[284] The Symposium did not just facilitate Japanese learning, but two-way intellectual exchange between Japanese and Western researchers produced ideas that whose importance in later decades is hard to overstate.

In his final address, Platzman stated:

> Now, at the conclusion of the Symposium, we feel very strongly that we wish to make a statement of our great appreciation for the tremendous scientific stimulation we have

[283] Ibid. For more analysis of some of the ideas circulated at the conference, see Dalmedico, 409-412; Shigeo Yoden. "Atmospheric Predictability." *Journal of Japanese Meteorology*, Vol. 85B (2007). 77-79. For a popular examination of the importance of chaos theory, see James Gleick. *Chaos: Making a New Science* (New York: Open Road Media, 2011). For a classic paper looking at how chaos theory impacted another scientific discipline, see Donald Worster. "The Ecology of Order and Chaos." *Environmental History Review*, Vol. 14 No. ½ (1990). 1-18.

[284] Yanai's contributions are described in Taroh Matsuno. "Prologue: Tropical Meteorology 1960–2010—Personal Recollections." *Multiscale Convection-Coupled Systems in the Tropics: A Tribute to Dr. Michio Yanai*. Ed. Robert G. Fovell and Wen-wen Tung (Chicago: Chicago UP, 2017). vii-ix.

> experienced as a result of these proceedings… It is now scarcely ten years since the first numerical weather prediction was made on a high-speed computer. In that incredibly short time, there has been a remarkable renaissance in the application of dynamical principles… a renaissance in which Japanese researchers have taken a leading role.[285]

Platzman, who exchanged ideas with Gambo in those earliest stages of Japanese research and worked with Kasahara later to operationalize Sasaki's theory, was more aware than most of the importance of Japanese research. Another participant who played a leading role in early NWP, Bert Bolin, concurred:

> I think we all feel that this symposium represents a milestone in the development in this field…we have got first-hand impression of your [Japanese participants'] important contributions to the field, and Japanese meteorologists will undoubtedly play an even more significant role in the future.[286]

The work of the NWP Group in the 1950s laid the groundwork for Japan's entrance onto the world stage of meteorological research. Through this new political and intellectual platform, Japan was able next to contribute to the next stage of modernization, that which tied Earth-space together to forge the first global system of weather data.

**The Satellite**

In 1980, the US National Oceanic and Atmospheric Administration (NOAA) produced a short-film introducing the Global Weather Experiment to a popular audience.[287] A short synopsis of this film opens up the questions that had arisen in Numerical Weather Prediction since the 1960 Tokyo Symposium. "Our job is to show how far ahead the weather shows its hand," states Verner E. Suomi, often considered the father of satellite meteorology, as the grainy picture fades

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[285] Quoted in an official report on the proceedings from H. Itoh. "International Symposium on Numerical Weather Prediction in Tokyo." *Journal of Japanese Meteorology*, Vol. 39 Issue 1 (1961). 46.
[286] Ibid, 47.
[287] National Oceanic and Atmospheric Administration. *The Global Weather Experiment: A Whole Earth View*. YouTube (Washington D.C.: Eliot A. Macklow and Peter Rosen Production, Inc., 1980.) https://www.youtube.com/watch?v=eKf-8CibNk8.

in. As the scene cuts to a rocket launch, the narrator intones: “The Global Weather Experiment is the largest international scientific experiment in history; 140 nations are participating. The laboratory is the whole planet Earth.”

Suomi then explains how the experiment will allow us to know the weather “for the first time… on all scales.” Cut to Joseph Smagorinsky, who, as noted above, would later praise the influential early work of the “Tokyo School.” Smagorinsky was also crucial to the revitalization of the primitive equations, and presented on the topic at the 1960 Symposium. Smagorinsky states that while NWP had advanced rapidly, further improvement would require an “extraordinary effort” to improve the “reliability” of data and range of forecasting. After a collage of images juxtaposed with narration emphasizing the societal needs for weather prediction and understanding, the basic physics of atmospheric motion are explained. While global observation networks had improved, the scale was simply not large enough: “the weather has global roots… linked in space and time” we are told, and forecasts beyond a week (medium and long-range), would require data collection from the entire planet.

The Global Weather Experiment is designed, as part of the Global Atmospheric Research Project (GARP) ongoing since 1967, to make use of the Global Observing System set up since 1963 under the World Weather Watch (WWW). Additionally, it has been timed to coincide with the launch of five new satellites (including Japan’s first weather satellite). The entire system of land stations, boats, balloons, planes, buoys, satellites is described, the latter also working to relay the info from the rest to central hubs. Smagorinsky reappears in these last minutes to explain how the real goal is to establish the “ultimate limits to prediction” and attain a complete set of observational data such that one can get as close as humanly possible to this limit. As the

picture fades to the strains of a violin quartet, the narrator concludes that the Experiment will give us "a whole earth point of view: a truly international experiment."

The motivations which the meteorologists speak of in this film had changed little since the Panel on International Meteorological Cooperation, chaired by none other than Jule Charney, had reported on *The Feasibility of a Global Observation and Analysis Experiment* to the US Committee on Atmospheric Sciences in 1966. They make three key points in this report. First, because "the large-scale elements of the atmospheric circulation are so strongly coupled in space and time that they can be understood only in combination… the atmosphere must be measured on a global scale." Weather constitutes a "single, self-contained physical system with all its parts in mutual interaction," and within a week, phenomena in one part of the globe can affect the whole.[288]

Secondly, the authors make a great deal of the discoveries and arguments that Lorenz had originally presented in 1960, which he more notably and concretely described a few years later.[289] It had been shown mathematically that the errors in initial data could be so small that no degree of perfect instrumentation could prevent chaotic development from spoiling indefinitely long forecasts; thus Smagorinsky's invocation of an "ultimate limit" to the range of forecasts. In a response to a question from Bert Bolin at the 1960 Symposium, Lorenz hinted at this much when he noted that even with mistakes "smaller than observational error," two otherwise equivalent forecast algorithms would become completely divergent with enough time.[290] As preparations for the Experiment later demonstrated, a fundamental task was to understand how

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[288] National Academy of Sciences: National Research Council. *The Feasibility of a Global Observation and Analysis Experiment: A Report of the Panel on International Meteorological Cooperation to the Committee on Atmospheric Sciences* (Washington D.C.: National Academy of Sciences, 1966). 4, 6-7.

[289] See Edward N. Lorenz. "Deterministic Nonperiodic Flow." *Journal of Atmospheric Sciences*, Vol. 20 No. 2 (1963). 130-141.

[290] Lorenz. *Proceedings of the International Symposium on Numerical Weather Prediction in Tokyo,* 635.

good forecasts could be in the face of this chaotic limit. To do so required a far more sophisticated global network of observations. This need to provide for the possibility for medium and possibly long-range forecasts in part motivated the Experiment.[291]

Finally, and most importantly, the authors explicitly write that "the saving factor is that a new dimension in observational capacity was added in 1957 by the advent of the earth-orbiting satellite."[292] Without such technological advancement, the global scale needed to push NWP to the next level in terms of range and accuracy would be unfeasible. One quote from the NOAA film is telling: whether with the "new way" of satellites or more traditional methods, "we make the atmosphere visible to the computer." I have argued thus far that synopticism and quantification represent two fundamental halves of meteorology modernity. However, as Charney's Panel points out, forecasting had reached a limit by the mid-1960s, proscribed most importantly by the discovery that weather is a chaotic system.[293]

Space power was needed to bring together a synoptic knowledge of weather over a vast scale and a quantifiable knowledge of weather as a set of numerically representable physical phenomena. It was the satellite which could extend the mind so as to gain a quantified set of data over huge swaths of space which could be integrated into algorithmic predictions. The satellite cohered these two strands by making longer range predictions via NWP viable through a synoptic global picture of the weather. Modern meteorology, in its mature form, was the result of forecasters coming to know the weather through Earth-space.

Some of the initial inspiration for satellite meteorology came as a result of Japanese wartime actions. During the war, Project Fu-Go was an attempt to ignite massive forest fires on

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[291] National Research Council. *The Feasibility of a Global Observation and Analysis Experiment*, 12-31.
[292] Ibid, 4-5.
[293] Ibid, 4.

the western coasts of the US and Canada using incendiary balloons transported via the jet stream. As yet another example of the overlooked meteorological insights of early Japanese researchers, the jet stream, a narrow band of strong winds that blows from west to east, was itself originally discovered by Wasaburo Oishi in the 1920s. Despite his attempts to broaden his readership in the west (albeit misguidedly through publishing his research in Esperanto), the meteorological community in general ignored his findings, and the jet stream was officially "discovered" decades later. However, the Japanese military did take note, and Oishi's observations were the basis for the attack. The attack itself caused a few minor wildfires and a handful of casualties, news of which was censored. A decade later, though, the story of the attack, and the knowledge that undergirded it, inspired William Kellogg and Stanley Greenfield to think about the usability of atmospheric data generated by high-altitude balloons. It was this project that evolved into the argument that "weather reconnaissance" via satellite could be of fundamental importance to weather prediction given the synoptic view of Earth thus afforded.[294]

The most important champion of this insight was Verner Suomi, who would speak during the Global Weather Experiment of the "whole earth view" satellites could offer. His technology was onboard the first practically functional weather satellite, TIROS (Television Infrared Observation Satellite), which was launched in 1960 and simply took photographic images of the Earth from orbit. These images provided a sense of what synoptic weather phenomena actually "looked like."[295] TIROS hinted at the possibility of a complete image of the weather at the

[294] For Oishi's place in the history of meteorology, see John M. Lewis "Ooishi's Observation Viewed in the Context of Jet Stream Discovery." *Bulletin of the American Meteorological Society*, Vol. 84 No. 3 (2003). 357-370. For Kellogg and Greenfield, see Helen Gavaghan. *Something New Under the Sun: Satellite and the Beginning of the Space Age* (New York: Springer-Verlag, 1998). 140-145.

[295] Gavaghan. *Something New Under the Sun*, 145-148. See also National Research Council of the National Academies: Committee on Scientific Accomplishments of Earth Observations from Space. *Earth Observations from Space: The First 50 Years of Scientific Achievements* (Washington D.C.: National Academies Press, 2007). 11-12, 19-21; Stanley Q. Kidder and Thomas H. Vonder Harr. *Satellite Meteorology: An Introduction* (San Diego: Academic Press, 1995). 3.

largest scale possible; the entire globe. Once continuous global coverage of the world's weather was captured, there was no more scale to be had.

However, synopticism alone was not enough. In their early reports in the 1950s, Kellogg and Greenfield did not yet emphasize the virtual monopoly that numerical methods would come to hold over the field. However, soon enough the mere qualitative images that satellites could produce, though synoptic, were inadequate. There arose something of a debate regarding the usefulness of satellites, given this limitation, and in 1969, the National Academy of Sciences wrote that "until satellites are able to generate [quantitative inputs], their use in modern meteorology will be at best supplementary."[296]

In that same year, however, the implementation of sounding technology, which could radiometrically read electromagnetic radiation that could be translated into those all-important quantities of temperature, moisture content, and more was first used aboard the NIMBUS-3. 1969 marks the beginning of satellite data being used in NWP. Moreover, the NIMBUS-3 SIRS sounder measured the *vertical* temperature profile of the atmosphere. Sounding technology like SIRS enabled meteorologists to appreciate and more carefully measure the 3-dimensional nature of weather phenomena.[297] Once satellites started giving "quantitative inputs," the door to modern meteorology fully opened: the synoptic global patterns of the weather could be "made visible to the computer."

In Japan, the history of satellites followed a nearly synchronous path, although the US occupation's ban on rocket manufacture until 1952 delayed technical developments. Japanese engineers, like those in the US, were inspired by the German rockets of the Second World War.

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[296] Gavaghan. *Something New Under the Sun*, 136.

[297] See Gavaghan on sounding technology. *Something New Under the Sun,* 134-135. See also National Research Council. *Earth Observations from Space*, 14, 21-22; Kidder and Vonder Harr. *Satellite Meteorology*, 7.

One scientist in particular, Hideo Itokawa, played the leading role in developing Japan's satellites. Immediately after the Occupation ended, Itokawa exclaimed that Japan would have "rockets in five years!" Though this promise initially provoked skepticism, during the International Geophysical Year (IGY) in 1957-1958 Japan contributed numerous sounding rockets, an important precursor to the GARP as it required international scientific cooperation on a large scale. By the mid-1960s, Itokawa and colleagues were working towards achieving indigenous satellite potential in Japan. However, as test satellites failed throughout the decade, inclinations in Japan turned increasingly toward using technology bought from the Unites States, and in 1969, an agreement with the Nixon administration formalized this agreement. Itokawa resigned, but with US technology, Japan launched its first satellite, *Osumi*, in 1970, thereby becoming the fourth nation in outer space.[298]

As this history shows, the international context is inseparable from Japan's early space program. Throughout the next decades, the issue of US aid versus indigenous production was paramount and molded the development of the program. However, while Japan was heavily dependent on US technology for decades, we should not imagine that this was a one-way relationship. After all, even in the 1950s Japan made positive contributions to the IGY. In the early 1970s, those first Japanese satellites also enabled discoveries of a new radiation belt. After 1969, one of Japan's space agencies, NASDA (National Space Development Agency of Japan), worked to develop a geostationary weather satellite, a project that ultimately produced *Himawari*

[298] There is not an abundance of secondary literature on Japan's early space program. The most comprehensive analysis I've found is Brian Harvey. *Emerging Space Powers: The New Space Programs of Asia, the Middle East, and South America* (Chichester: Praxis, 2010), esp. 1-35. Although the analysis is more of a chronicle for the early years, see Steven Berner. *Japan's Space Program: A Fork in the Road?* (Santa Monica: RAND, 2005). For a focus more on Japanese space policy and military applications, see Saadia Pekkanen, Paul Kallender-Umezu. *In Defense of Japan: From the Market to the Military in Space Policy* (Stanford: Stanford UP, 2010).

*I* in 1977, which became Japan's primary contribution to the Global Weather Experiment.[299] Globalizing the history of Japan's space program does not require that we see Japan as the passive recipient of US technology and science, but as an active partner in the development of global trends, where domestic and international developments were intertwined.

Not only did the NASDA's domestic push to create a geostationary satellite coincide and integrate with the GARP program, but those original emigres from the NWP Group, who had been working in America since the 1950s, made fundamental contributions in the 1960s and 1970s both to the field of NWP (a second Tokyo Symposium was held in 1968) and towards the challenges of assimilating satellite sounding data. Akira Kasahara, who earlier had worked to integrate storm tracking techniques into the US Weather Bureau's models, published on the observational systems and aspirations of the GARP program in 1972. Writing for the American Meteorological Society, he stressed the need to obtain enhanced observational capabilities as well as models that could assimilate this information. Satellites would play a key role:

> The recent advent of earth-orbiting satellites has had a vast impact on meteorological observation. Instruments aboard meteorological satellites are capable of observing the vertical profile of the temperature between the earth and the satellite. Since these satellites pass over most of the Earth's surface in a 24-hour period, the global distribution of temperature is obtained continuously in time.[300]

These remarks point again to the way satellites integrated quantitative and synoptic epistemologies. While earlier meteorologists since TIROS had worried that satellites could not provide usable data, by the time the Global Weather Experiment was coming together in the

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[299] Harvey. *Emerging Space Powers*, 23, 29-30. Note that for most of its history, the Japanese space program was bifurcated between NASDA and the Institute of Space and Astronautical Science (ISAS). The former was an applied division that focused on commercial and industrial uses while the latter was more theoretical. NASDA and ISAS vied for funding throughout the decades, the latter naturally at a disadvantage. The two were merged under the current Japan Aerospace Exploration Agency (JAXA) in 2003 (Harvey. *Emerging Space Powers*, 22-23; Berner. *Japan's Space Program*, 12-16). See also William D. Wray. "Japanese Space Enterprise: The Problem of Autonomous Development." *Pacific Affairs*, Vol. 64 No. 4 (1992). 463-488.

[300] Akira Kasahara. "Simulation Experiments for Meteorological Observing Systems for GARP." *Bulletin of the American Meteorological Society*, Vol. 53 No. 3 (1972). 253.

1970s, radiometric sounding technology had apparently proven the worth of satellite data to many. Further studies on assimilating satellite data were done by Kikuro Miyakoda, another Tokyo School émigré who had helped Sasaki develop his models in 1954. Miyakoda later served on the Advisory Panel for the Global Weather Experiment, and the foundational 1978 report to the US GARP Committee on the implementation of the project is filled with citations to this work. Syukuro Manabe, also an émigré, served on the GARP Committee.[301] All of this is to say that Japanese emigrants from the NWP Group played an important role in the integration of satellite data into NWP and the Global Weather Experiment. As some scholars have been emphasizing of late, the history of Japan, or any country for that matter, must be internationalized to include the histories of its emigrants; Japanese-American history should also be recognized as Japanese history.[302]

Looking back to the country itself, Japan and NASDA's main contribution, *Himawari*, was part of a coordinated effort to synchronize the Global Weather Experiment with strategic satellite launches to gain global coverage. *Himawari* was one of five geostationary satellites that were part of this system, the others being operated by the United States and the European Space Agency. *Geostationary* satellites, like *Himawari I*, are a specific type of satellite, so-named because they orbit at the same speed the Earth turns, thus allowing them to remain stationary over a single point over the equator, enabling them to see weather develop in one location over time. *Himawari*, like the other satellites, was equipped with Visible and Infrared Spin-Scan Radiometric sensors (VISSR) that enabled atmospheric sounding that could be assimilated into

[301] FGGE Advisory Panel to the US Committee for the Global Atmospheric Research Program. *The Global Weather Experiment - Perspectives on its Implementation and Exploitation: Report of the FGGE Advisory Panel to the US Committee for the Global Atmospheric Research Program* (Washington D.C.: National Academy of Sciences, 1978). iii, 1-21.

[302] For a good example, see Eiichiro Azuma. *Between Two Empires: Race, History, and Transnationalism in Japanese America* (New York: Oxford UP, 2005).

NWP.[303] Himawari specifically was used to measure wind direction/speed (or wind vector) and sea-surface temperature. A simple graphic displaying the respective coverage of the five satellites powerfully reveals the extent of Japan's involvement in the Global Weather Experiment (Fig. 2.5): "Located at 70˚E, the satellite provides a unique view of atmospheric events in that part of the world…"[304]

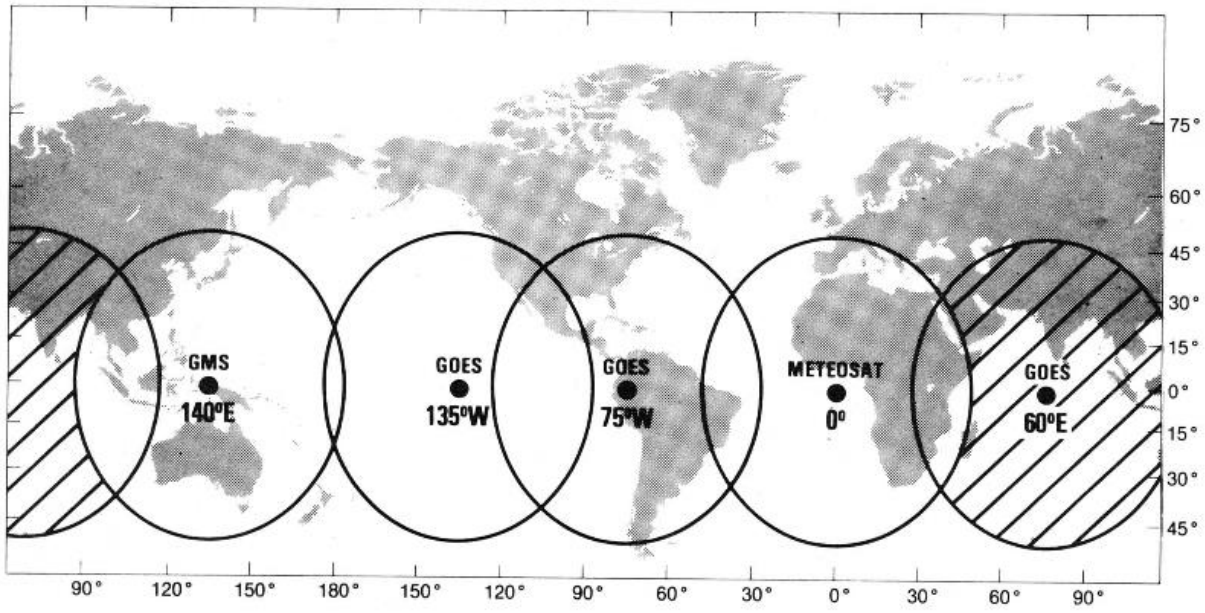


Figure 2.5 (GMS is Himawari)[305]

By most scientists' measures, the Global Weather Experiment was a great success, providing synoptic data at a large scale. The Experiment enabled forecasts to be extended significantly into the middle-ranges since the 1980s. As one group of scientists summarized in 1986: "without [the experiment], what advancements would have been realized [in longer range prediction]? That is impossible to know. But it is certain that the major concerted effort of 140

[303] Harvey. *Emerging Space Powers*, 30; FGGE Advisory Panel. *The Global Weather Experiment*, 27.
[304] R.J. Fleming et al. "The Global Weather Experiment 1: The Observational Phase through the First Special Observing Period." *Bulletin of the American Meteorological Society*. Vol. 60 No. 6 (1979). 651-652.
[305] Ibid.

nations and the resulting research and development have been significant indeed."[306] Satellites played a fundamental role through collecting novel sounding data of neglected regions in the upper atmosphere or oceans in the Southern Hemisphere (both of which together Suomi once humorously termed the "ignorosphere").[307] Additionally, the "satellite-balloon-buoy-radiometric system" as essentially described by Charney and others in 1966 was put to use during the Experiment such that satellites also served to centralize and relay data from other measurements on the ground and in the sea and air.[308]

The Global Weather Experiment, and the contributions of Japan and Japanese emigres to its success, played an important role in bringing satellites into mainstream meteorology, a goal that was achieved during the 1980s.[309] In the 21st century, the National Research Council concludes that satellite data provides by far the majority of initial data for NWP and "has the greatest impact of any measuring technology in improving forecast skill."[310] Meteorology began to modernize as forecasters extended their minds through telegraphs and computers, but it was only *through* (in both senses of the phrase) Earth-space, that the modern epistemology of weather was created.

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[306] Julia Nogues-Paegle. "Summary of the National Conference on the Scientific Results of the First GARP Global Experiment January 14–17, 1986 1489." *Bulletin of the American Meteorological Society*, Vol. 67 No. 12 (1986). 1489.
[307] Gavaghan. *Something New Under the Sun*, 152.
[308] National Research Council. *The Feasibility of a Global Observation and Analysis Experiment*, 4-5.
[309] Gavaghan. *Something New Under the Sun*, 138-139.
[310] National Research Council. *Earth Observations from Space*, 23. For similar points, along with a general analysis of the importance of satellite data and the challenges forecasters have to account for, see Jean-Noel Thepaut. "Satellite Data Assimilation in Numerical Weather Prediction: an Overview." *Seminar on Recent Developments in Data Assimilation for Atmosphere and Ocean*. European Centre for Medium-Range Weather Forecasts. (2003).

## Part 2: Modern Meteorology: Between Weather and Society

### Incommensurability

The emergent reign of the satellite was not the end of the story, as these modern forms of knowledge often failed in enabling people to control the effects of weather. Two frameworks, Thomas Kuhn's notion of incommensurability and the recent field of weather and society studies, are tools with which to understand how epistemic gaps were generated between experts and laypeople and how those gaps came to have the potency they do. As tools, my presentation of these ideas will be selective and non-exhaustive: I will take from them what I need to examine the cases I will look at later and as little else as possible while still appreciating the context of the ideas. Naturally, this approach will not satisfy disciplinary specialists, but what it lacks in nuance and detail I hope to make up for in scope and applicability: a fox's approach.

In 1962, two philosophers of science, Thomas Kuhn and Paul Feyerabend, both introduced a similar but different notion of incommensurability into the philosophy of science. Here, I will focus on Kuhn's notion, which has received more attention generally in mainstream literature. In his groundbreaking *The Structure of Scientific Revolutions*, Kuhn laid out a philosophy and history of scientific change wherein knowledge did not merely accumulate over time, converging more and more closely to the reality of nature. Rather, science periodically experienced revolutionary "paradigm shifts" whereby the entire way of thinking about the world jumped suddenly into an entirely new scheme of concepts, focuses, practices, and justifications that were unrecognizable in the previous scheme. Different paradigms could not be compared to each other from a neutral standpoint, merely by seeing which one corresponded better to nature, because the methodologies and concerns of different paradigms diverged. Kuhn's work

effectively debunked older notions of positivism and launched new, field-defining research paradigms itself in the history, philosophy, and sociology of science.

Holding Kuhn's own scheme together is a notion of incommensurability between paradigms. Kuhn notoriously gave slippery, disjointed definitions of exactly what this incommensurability entailed, definitions that changed a great deal over time. Most generally, incommensurability entails that different paradigms "lack a common measure" by which to compare them. Specifically, Kuhn saw three ways in which this was the case: (1) paradigms can be *methodologically incommensurable*, meaning they carry different evaluative metrics to establish their theoretical virtues (or at least give weight to different virtues over others). In other words, what counts as good for one theory may not be the same as what counts as good for another. (2) Paradigms can be *semantically incommensurable*, meaning the taxonomic categories of one theory do not match up with those of another. Kuhn gives the example of the shift from Ptolemaic geocentrism to Copernican heliocentrism. In the former, the term "planet" referred to the Sun and the Moon, but not the Earth, while in the latter, "planet" referred to the Earth, while the Sun became a "star" and the Moon a "satellite." For Kuhn, these conceptual schemes are incommensurable because the Ptolemaic notion of "planet" cannot be mapped onto any single category of thing the Copernican theory describes. Finally, (3) paradigms can be *perceptually incommensurable* because many observations are *theory-laden*. In other words, the raw observations themselves are not theory-independent and each observer comes to observe the world with their own theoretical baggage influencing what they are going to see.[311]

[311] For the most recent edition, see Thomas Kuhn. *The Structure of Scientific Revolutions.* 50th Anniversary Edition. First published in 1962 (Chicago: Chicago UP, 2012). Two articles in the *Stanford Encyclopedia of Philosophy* have been of great use to me as well: Alexander Bird. "Thomas Kuhn." Last Revised on 31 October 2018. https://plato.stanford.edu/entries/thomas-kuhn/; Eric Oberheim and Paul Hoyningen-Huene. "The Incommensurability of Scientific Theories." Last revised on 4 September 2018. https://plato.stanford.edu/entries/incommensurability/. See also Howard Sankey. "Kuhn's Changing Concept of

Over time, philosophers have emphasized this perceptual notion less while (1) and (2) are discussed more often. Among these, (2) is where the Kuhn's theory has become most controversial. It is also this notion that Kuhn developed the most after 1962 and is perhaps at the root of what he came to see as the fundamental problem. In Part 2, however, I will focus only on (1), methodological incommensurability, and I will return to the semantic/taxonomic interpretation in Part 3. While Kuhn and others have largely applied incommensurability to competing scientific theories, I think it also offers many tools that can be usefully applied to the gaps between expert and layperson paradigms of thought, and methodological incommensurability in particular allows us to understand more concretely some of the ideas that have emerged from weather and society studies.

**Weather and Society Integrated Studies**

How do people act during extreme weather events? How do they react to forecasts of them? These are questions that are fundamental to the ability of governments and risk managers to protect against or *control* the effects of storms, droughts, or fires. However, in the genealogy outlined in Part 1, these concerns played little role in how meteorology became modern. That narrative, absent the concerns I will raise now, is misleadingly triumphalist, suggesting that the science progressed to gain greater and greater knowledge and power in a linear manner. Accuracy, however, is not control, and the modernity represented by synoptic and quantified methods was not correlated in any straightforward way with the conquest of natural forces under

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Incommensurability." *British Journal for the Philosophy of Science*, Vol. 44 (1993). 759-774; "Taxonomic Incommensurability." *International Studies in the Philosophy of Science*, Vol. 12 No. 8 (1998). 7-16; Lena Soler. "The Incommensurability Problem: Evolution, Current Approaches and Recent Issues." *Philosophia Scientiae*, Vol. 8 No. 1 (2004). 1-38; Xiang Chen. "Kuhn's Latest Notion of Incommensurability." *Journal for General Philosophy of Science*, Vol. 28 No. 2 (1997). 257-273.

human minds and instruments. Understanding how modern meteorology failed in some ways to control the effects of severe weather events requires an interdisciplinary approach. The scientists discussed earlier implicitly assumed that that people would "rationally" absorb these "better" scientific predictions, once communicated, and make themselves safe. It is only recently that scholars working at the interstices of meteorology and social science have tried to show that any approach to forecasting cannot assume this.

While there is of course a long intellectual history of social scientists and others studying the social dimension of weather phenomena, it was only around the turn of the 21st century and after that this work began to gain a foothold in the meteorological community. The strongest statement of its resonance came with formation in 2005 of a Weather and Society Integrated Studies (WAS*IS) program under the US Weather Research Program. The aim of WAS*IS was to connect a network across fields to work towards the goal of integrating social scientific findings on behavior and perception into forecasting methodology. While WAS*IS formally ended in 2012, it had many spin-offs, often associated with the effective leader of the movement, Eve Gruntfest, who only in 2018 wrote the first "textbook" on the subject.[312]

The late arrival of these interdisciplinary developments points to the fundamental problem that meteorology faced as it modernized: while forecast accuracy was increasing, the epistemic methods used to do so were themselves increasingly detached from the experiences of the laypeople whom the forecasts were supposed to protect. To be sure, forecast accuracy generally has played a large role in mitigating the fatality rate of extreme weather events. However, it is easy to overstate this claim, as many costs have risen even as forecasts have

[312] Eve Gruntfest. *Weather and Society: Toward Integrated Approaches* (Hoboken: John Wiley & Sons, 2018). 29-44

improved.[313] More importantly, this generalization neatly glides over the problems that these gaps have incurred. WAS*IS and other efforts, using cutting edge research, have only recently begun to bridge the communication breakdown between experts and laypeople.

The geographer Diane Liverman identifies some of the fundamental myths about forecasting that have sabotaged modern attempts to control for the effects of weather. For example, meteorology was modernized according to the principle that "physical science alone has the answers to the question of how to reduce loss of life and property from severe weather." Forecasters often assume, echoing economic theories about rational agency, that people just need more information that is more accurate in order to make the "correct" risk-averse decisions:

> Meteorological agencies think that if they simply improve their forecasts to be more accurate and more precise that people will do the right thing in the time they have to reduce their vulnerability. Improving forecasts is a good thing, but it is not the only thing that guarantees that vulnerable people will be motivated to change their behavior.[314]

Overall, the WAS*IS framework ultimately makes a number of strong suggestions that can be more or less generalized across researchers. First, there are many different kinds of "users" who receive meteorological information from experts. There is no one size fits all model.[315] Second, forecasters cannot homogenize a notion of "rationality" and use it to expect people to behave in self-interested, risk-averse ways given accurate forecasts. On the one hand, most researchers in this area believe that rationality is more complex to begin with. Laypeople often simply have fundamentally different concerns than risk managers do, and what is "rational" for them to do during severe weather events may often seem irrational. Many people stay put

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[313] Gruntfest. *Weather and Society*, 2; Roger A. Pielke Jr. "Asking the Right Questions: Atmospheric Sciences Research and Societal Needs." *Bulletin of the American Meteorological Society*, Vol. 78 No. 2 (1997). 261.
[314] Gruntfest. *Weather and Society*, 45-46.
[315] National Research Council of the National Academies: Committee on Estimating and Communicating Uncertainty in Weather and Climate Forecasts. *Completing the Forecast: Characterizing and Communicating Uncertainty for Better Decisions Using Weather and Climate Forecasts* (Washington D.C., National Academies Press, 2006). 16-22.

during evacuations or drive during floods due to financial or personal concerns and obligations. Moreover, as Louise Lemyre emphasizes, viewing laypersons' risk perception as merely misguided is rather "pointless" because whether it is rational or not, the goals of forecasters should be to produce forecasts that save lives and reduce costs.[316] To achieve these goals, they simply must take into account the sociological and cognitive questions involved in how people actually act and react during severe weather events.

What WAS*IS approaches are really homing in on is a sort of methodological incommensurability between expert and lay evaluations of forecasts. Allan Murphy, trained as a meteorologist, makes these concerns more explicit. His 1993 "What is a Good Forecast? An Essay on the Nature of Goodness in Weather Forecasting," effectively a meta-normative analysis of meteorological practice, lays out the different meanings that "good" can have when applied to forecasts. "Type 1 goodness" he calls *consistency*, meaning that a good forecast corresponds to the forecaster's judgments; in his products, the forecaster accurately represents his beliefs regarding the risks and probabilities involved. Additionally, Type 2 goodness refers to a sense of *quality*, wherein a good forecast is accurate in the way it represents the meteorological events; forecasts are good if they are *true*. It is Type 2 goodness Murphy believes, with Liverman effectively, that most meteorologists have focused on. However, in addition to consistency and quality, Murphy adds that good forecasts can be good insofar as they have *value*, meaning that the users themselves can use the forecasts to avoid costs and attain benefits. Type 3 goodness, according to Murphy, is less recognized or appreciated, despite the fact that it alone provides the

[316] Louise Lemyre et al. "Psychosocial Aspects of Risk Perception and Communication." *Weather and Climate Risk Communication*. Ed. Bernard Motulski et al (Quebec: Quebec UP, 2018). 73. See also National Research Council. *Completing the Forecast*, 22-28 for an overview of behavioral science of user perceptions and reactions.

actual impetus to make forecasts presumably.[317] As Roger Pielke has said more recently, "a perfect forecast is of no value if it is unavailable to or unusable by a decision-maker."[318]

What the difference between *value* and *quality* embodies are the very different metrics that laypeople and experts generally have used in assessing what counts as a "good" forecast. Murphy explicitly states a kind of methodological incommensurability when he writes that "forecasters and users generally use fundamentally different methods of evaluating forecasts."[319] Value, closely linked to the unwanted costs of severe weather events, is tied to the controllability of those events. As such, the conclusions that have arisen from Murphy and other "WAS*IS-ers" imply that there is a methodological incommensurability between the standards that drove modern meteorology and those of lay users, the former largely relying on a notion of quality while the latter rely necessarily on value. The very standards used by forecasters often made their work incommensurable with laypeople's needs, and it was this incommensurability that drove a gap between the accuracy and value of forecasts that weakened experts' ability to control weather effects.

Before turning to Japan as a case-study for this control gap, it is important also to establish some of the theoretical underpinning for a specific avenue within weather and society studies that has even more provocative implications for this question of control. In his classic work of psychology from 1984, Shlomo Breznitz popularized the so-called "cry-wolf effect." In his experiments, Breznitz found that people would become numb to certain risks if the signals announcing them repeatedly turned out to be false alarms. This "false-alarm effect" (FAE) as Breznitz referred to it, is analogous to the classic story of the boy who cried wolf, as the repeated

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[317] Allan H. Murphy. "What Is a Good Forecast? An Essay on the Nature of Goodness in Weather Forecasting." *Weather and Forecasting*, Vol. 8 No. 2 (1993). 281-293.
[318] Quoted in Gruntfest. *Weather and Society*, 36.
[319] Murphy. "What is a Good Forecast?" 292.

lies of the boy ultimately result in the populace into not trusting him even when he later tells the truth. In Breznitz's terms, there is "credibility loss" over time.[320] Today, this notion is also often referred to as "warning fatigue." In 1984, Breznitz wrote suggestively in his introduction that "with the rise of sophisticated early warning systems, false alarms are inevitably on the increase, and their psychological impact may well turn out to be the most vulnerable link of many warning systems."[321]

The implications of Breznitz's conclusions for weather forecasting are immediately apparent. As a discipline focused on the quality of forecasts, i.e. their accuracy, a rising false alarm rate (FAR) in forecasts is inevitable as they are more sensitive to the conditions that could potentially give rise to severe weather:

> Not long ago, people knew about an approaching hurricane when it was practically upon them. Consequently, the number of false alarms was much smaller. These days, with sophisticated satellite pictures, even distant, low probability events, are easily detected and reported in the media. However, only a very tiny number of detected hurricanes actually hit a particular area, thus producing a large number of false alarms.[322]

As meteorological modernity inspired new confidence in accurate and long-range forecasts, severe weather could be known in advance more precisely, but putting in place a system of early warnings also meant a much greater chance of false alarms. If warning fatigue is real, then the increasing accuracy of forecasts is correlated with an emergent risk as increasing exposure to false alarms can numb people to severe weather threats. Just like with the wolf, the effects of warning fatigue are potentially catastrophic.

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[320] Shlomo Breznitz. *Cry Wolf: The Psychology of False Alarms* (Hillsdale: Lawrence Erlbaum Associates, Inc. 1984). esp. 9-16

[321] Ibid, xiii.

[322] Shlomo Breznitz. "Cry Wolf: When Experience Becomes Fateful." *Psychology Today*. 16 May 2012. https://www.psychologytoday.com/us/blog/maximum-brainpower/201205/cry-wolf-when-experience-becomes-fateful.

While meteorologists are well-aware of the effect, and false alarm rates are carefully tracked, it is nonetheless true that it is only with the modern confidence in early warning potential, driven by need to increase the goodness of forecasts solely via their quality, that warning fatigue could have arisen.[323] To be fair, many have dismissed the notion of warning fatigue as a "myth" unsupported by empirical evidence. However, more recently, in the first comprehensive study and review of the topic, Brenda Mackie has asserted that the literature on the "myth" of warning fatigue is often itself contradictory as authors explicitly refer to the effect as a "myth" while implicitly relying on its explanatory usefulness. Moreover, her own work on Australian bushfires gives new life to the concept, evidenced not in an experimental setting like with Breznitz, but in a real-life context.[324]

If we agree with Mackie that warning fatigue is a very real and dangerous phenomenon that needs to be taken into account, the grand narrative of modernity is disturbed in an important way. Modernity, represented in the epistemic concepts and tools that meteorologists exploited to create more accurate forecasts, did not simply allow experts to gain more control over the natural costs of weather. The same methodological incommensurability that allowed forecasters to overlook the modern need to translate forecasts to make them valuable also generated new risks.

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[323] For an example of FAR reduction, see "National Weather Service Birmingham AL Reduced Tornado Warning False Alarm Rate by 31% Since April 2011." False Alarm Reduction Research. *National Weather Service*. https://www.weather.gov/bmx/research_falsealarms.

[324] Brenda Mackie. "Warning Fatigue: Insights from the Australian Bushfire Context." Thesis. University of Canterbury (2013). esp. 10-26. See also Mackie. "Crying Wolf: The Myths on Warning Fatigue." *Bushfire CRC*. http://www.bushfirecrc.com/news/news-item/crying-wolf-myths-warning-fatigue. For an interview clip on the topic, see Mackie. "Is Warning Fatigue Real." *Bushfire CRC*. http://www.bushfirecrc.com/files/warning-fatigue-real-brenda-mackie. For a "myth" perspective, see Lindsey R. Barnes and Eve C. Gruntfest. "False Alarms and Close Calls: A Conceptual Model of Warning Accuracy." *Weather and Forecasting*, Vol. 22 No. 5 (2007). 1140-1147. However, in her aforementioned book, Gruntfest cites Mackie's work as positive evidence for warning fatigue (*Weather and Society*, 172-173). For an insightful blog post referring to Mackie's work, see Castle Williams and Paul Miller. "Fighting Fatigue: The Role of Warning Frequency in the Weather Enterprise." *The Weather Social: The Social Side of Communicating Weather*. 9 September 2016. https://thewxsocial.com/2016/09/09/fighting-fatigue-the-role-of-warning-frequency-in-the-weather-enterprise/.

**Quality and Value in Japanese Forecasting Since 1980**

The Japan Meteorological Agency's 2015 report on the modernization of Japan's meteorological services offers a simple story of typhoon forecast improvement. With advances in satellite data and NWP models in the 1980s, JMA forecasts were improved in 1988 via the integration of a global spectral model with Japan and Asia models. The global model also enabled the implementation of a specific typhoon forecast model (TYM) over a more limited area.[325] By the end of the 1980s, 48-hour forecasts were feasible, and a decade later, the Japan Meterological Agency (JMA) could make 72-hour forecasts as well.[326]

The models were updated further in 1996 in line with enhanced computer technology. These improvements allowed for higher resolutions and greater 3-dimensional analysis.[327] By 2009, models and data availability allowed for typhoon track and intensity predictions to be communicated to the public five days in advance. However, this notion of "improvement" conceals its own standards. According to the 2015 report, "typhoons are the most disastrous severe weather events in the northwestern Pacific region… the accurate prediction of their locations and intensities has always been a vital challenge for JMA."[328] In this statement, it is assumed that the value of the forecasts (i.e. mitigating those disastrous effects) is correlated to the accuracy of their predictions. As Murphy's work shows, this relationship is not so obvious. During the last few decades in which modern meteorology has advanced, the JMA has focused on improving the quality of its forecasts with little attention to the social dimensions involved.

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[325] See Takeo Kitade. "Numerical Forecasting in Japan." *Meteorology and Environmental Sciences: Proceedings of the Course on Physical Climatology and Meteorology for Environmental Application*. Ed. Rudolfo Guzzi et al (Singapore: World Scientific Publishing, 1990). 337-352. In the same volume, see his "Typhoon Forecast Model in Japan Meteorological Agency." 353-374.

[326] Hatori et al. *Modernization of Meteorological Services*, 34.

[327] Masashi Nagata et al. "Enhanced Accuracy of Typhoon Prediction of the Advanced Numerical Models at JMA." Technical Review No. 2. RSMC Tokyo – Typhoon Center (1998).

[328] Hatori et al. *Modernization of Meteorological Services*, 34.

One of the most notable changes in the JMA's services came in 2013 as a response to the 2011 Tohoku Earthquake and Tsunami. As became clear in the aftermath, the JMA's forecasts were inadequate in their conveyance of information to the public, as more than 20,000 died or went missing. In response to the scale of the disaster and public criticism, the JMA updated its early warning forecasts to create, as one official pamphlet described "a new service to protect life."[329] These changes revolved around changing the wording and implementations of warnings to convey the severity involved and introduced a new category of Emergency Warning for "phenomena are expected to be of a scale that will far exceed the [earlier] warning criteria."[330]

However, these changes were hampered by the same misunderstandings that WAS*IS studies have uncovered. According to the JMA, the problem lay in the inability to convey accurate information to lay users. The existing forecast system either failed to transmit the information, or its categories failed to convey the actual severity of the threats. As Kyoko Arai emphasizes in her criticism of the updates, their authors did not take account of relevant social science needed to make sense of lay reception of forecasts. As a linguist, Arai's criticism focuses on how users' interpretation of the language in forecasts and warnings differ from forecasters' and officials' intentions. Arai criticizes specifically the use of passive constructions, polite speech, and ambiguous and overly-complex statements.[331] As Arai further notes, "[interpretive] contexts can be supplied by knowledge (memories), sensory perceptions, and the addressee's

[329] A link to this pamphlet can be found at "Emergency Warning System." *Japan Meteorological Agency*. http://www.jma.go.jp/jma/en/Emergency_Warning/ew_index.html.
[330] Ibid.
[331] Kyoko Arai. "How to Transmit Disaster Information Effectively: A Linguistic Perspective on Japan's Tsunami Warnings and Evacuation Instructions." *International Journal of Disaster Risk Science*, Vol. 4 No. 3 (2013). 150-158.

inferences."[332] As such, blackouts which disabled people's ability to see the effects of the disaster on TV also hampered their ability to understand the threat.[333]

As the later journalistic reports of the 2018 West Japan Floods demonstrated, these control gaps bear significantly on disaster mitigation in Japan today. So many residents did not evacuate, not only because they did not have the correct information or did not receive it fast enough, but also simply because their own embodied experiences of weather trumped expert invocations to leave. Many remembered previous floods and did not really believe the risks were real. Others stayed at home "watching the situation" develop.[334] Later in August, after Typhoon Jebi struck Japan, field reports yielded similar results from surveys. In one town that experienced storm surge disasters, 90% of respondents had never experienced flooding before, and many did not believe that there was any real threat.[335]

For forecasts to be valuable, they need to break through the communication barrier and avoid measuring the goodness of forecasts in ways incommensurable with what people on the ground actually need forecasts to do. Modernity does not only make headway against control gaps that have always existed in risk mitigation, but it itself generates new gaps that only interdisciplinary social research can solve by reconnecting the abstract synoptic and quantified epistemologies of modern meteorology with the grounded experiences of laypeople.

Among these social dimensions, warning fatigue is as significant in Japan as it is elsewhere. Arai cites research that describes how the "cry wolf" problem "is a real one" that caused casualties during the 2011 Tsunami as earlier tsunami false alarms the previous year had

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[332] Ibid, 151.
[333] Ibid, 154.
[334] Board. "'I Watched my Neighbor Get Swept Away,'"
[335] Tomoyuki Takabatake et al. "Field Survey of 2018 Typhoon Jebi in Japan: Lessons for Disaster Risk Management." *Geosciences*, Vol. 8 No. 11 (2018). 424-426.

made people dubious and complacent. In 2010, the JMA apologized for this case of over-warning: "If we do that all the time, we cry wolf and lose credibility… We have to improve." Likewise, an earlier news report from 2007 described how thousands ignored tsunami warnings: "[the JMA] issues tsunami warnings even when only splashes are expected." Japanese newspapers put the blame on the false alarm effect, as "massive tsunami warnings" earlier that year amounted to only "small waves."[336]

This response misleadingly suggests that warning fatigue might just be a case in which greater accuracy is needed. While better science does reduce false alarm rates naturally, it was exactly this confidence in precision that allowed for warning fatigue to emerge as a new risk in the first place. Warning fatigue is a problem embedded in the embodied experiences of grounded users. As Breznitz puts it, "the main problem seems to be that our brains are incapable of not learning from experience."[337] False alarm rates are not such a big problem for the quality of forecasts, and if people were rational in the way forecasters often assume, then warning fatigue would not be worrisome because people would accurately perceive new risks independently of their irrelevant past experiences.

Warning fatigue revolves largely around low probability events that are predicted to happen despite this slight chance. To many, warning fatigue is largely an effect of forecasters' reliance on so-called deterministic forecasting, wherein future weather events are either said to occur or not occur, with no reference to uncertain chances. Future events have set, certain outcomes that are predicted and communicated. Deterministic forecasting is in contrast to

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[336] Arai. "How to Transmit Disaster Information Effectively," 157. Linda Sieg. "Japan Agency 'Sorry' After Tsunami Less than Feared." *Reuters*. 1 March 2010. https://www.reuters.com/article/us-quake-chile-japan-tsunami/japan-agency-sorry-after-tsunami-less-than-feared-idUSTRE6200W920100301. "Report: Thousands Ignored Tsunami Warnings in Japan." *Fox News*. 14 January 2007. https://www.foxnews.com/story/report-thousands-ignored-tsunami-warnings-in-japan.

[337] Breznitz, "Cry Wolf: When Experience Becomes Fateful."

probabilistic forecasting, which gives future events a likelihood of occurring. Probabilities of precipitation (PoP) are the most common form, such as a 60% estimate that it will rain tomorrow.

Overall, WAS*IS researchers tend to agree that communicating uncertainty via probabilistic forecasting is often superior to deterministic methods. The National Research Council even wrote a detailed report on just this subject.[338] Much research suggests that warning fatigue specifically can be mitigated by probabilistic forecasting, as credibility loss is less likely if low chance events are reported as such.[339] This is true in the Japanese case as well, and some Japanese researchers have suggested after the aforementioned 2010 tsunami false alarm that the JMA should report uncertainty information.[340]

While probabilistic forecasting of disasters often has shown positive outcomes on both the value of forecasts as well as their consistency (because forecasters themselves are uncertain), deterministic forecasting is more often the norm.[341] The reasons for this trend are due precisely to the developmental path of modern meteorology. As quantification allowed forecasters to think of weather phenomena as prescribed by deterministic physical laws of the atmosphere, it led to the development of NWP models that used these deterministic laws to calculate future events. While the popularization of chaos theory seemed to worry forecasters and expose the limits of determinism, the global turn that followed satellite technology further enhanced the predictive

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[338] See National Research Council. *Completing the Forecast.*

[339] Ibid, 69; Jared LeClerc and Susan Joslyn. "The Cry Wolf Effect and Weather-Related Decision Making." *Risk Analysis: An International Journal*, Vol. 35 Issue 3 (2015). 385-395.

[340] See Masanobu Kanai and Toshitaka Katada. "Issues of Tsunami Evacuation Behavior in Japan: Residents Response in Case of Chilean Earthquake in 2010." *Solutions to Coastal Disasters 2011: Proceedings of the 2011 Solutions to Coastal Disasters Conference*. Ed. Louise Wallendorf et al (Reston: American Society of Civil Engineers, 2011). 422

[341] On the relationship between consistency and deterministic forecasting, see Murphy. "What is a Good Forecast?" 283.

capability of deterministic forecasts.[342] In other words, meteorologists in Japan and elsewhere modernized their discipline by focusing on quality, which meant that forecasts became deterministic in order to track the deterministic laws of atmospheric physics. In the process, the theoretical virtues of consistency and value were sidelined in the quest to match science to reality. Controlling for the effects of nature, however, turns out to be much more complex than simply having correspondence between it and scientific models.

But we should not imagine that probabilistic forecasting solves the question of incommensurability altogether. Meteorology was modernized as forecasters got out of their heads, first through extending their minds through weather maps and telegraphs, then through computational crutches, and finally through satellites spread across Earth-space. In doing so, they distanced themselves from the embodied perspectives of grounded observers. Gruntfest writes that "some people have little confidence in official forecasts, preferring to 'look out the window' or rely on folk methods, 'gut readings,' or previous experience."[343] Likewise, Arai and other Japanese researchers responding to the 2013 Emergency Warning System write about cognitive dispositions that often require appeals to memory and sensation to express warnings effectively.[344] In support of this, Mackie more conclusively writes:

> What happens after a disaster warning of some magnitude is issued? More importantly, what do people typically do? The literature shows that people most often revert to their own evaluation of their environment, checking the temperature, wind direction or horizon, looking for clues that will either confirm or invalidate the warning. Social networks come into play, where neighbours are called upon to provide more cues not immediately available.[345]

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[342] National Research Council. *Completing the Forecast*, 7-8.
[343] Gruntfest. *Weather and Society*, 3.
[344] See Arai. "How to Transmit Disaster Information Effectively," as well as more recently Anawat Suppasri et al. "The 2016 Fukushima Earthquake and Tsunami: Local Tsunami Behavior and Recommendations for Tsunami Disaster Risk Reduction." *International Journal of Disaster Risk Reduction*, Vol. 21 (2017). 323-330.
[345] Mackie. "Crying Wolf: The Myths on Warning Fatigue."

To effectively combat warning fatigue and other sociological dimensions of forecasting, what is needed is an "end-to-end" approach that looks at the forecasting process from the initial data all the way to the reception of lay users.[346]

## Part 3: The Kobe Earthquake and Situated Knowledge in Earth-space

### InSAR Analyses after 1995

Thus far, in focusing on the incommensurability between lay and scientific approaches to weather, I have left open the question of *truth*; did scientific analyses through Earth-space even always approach a direct correspondence with reality? Beyond meteorology, satellite remote sensing has dramatically changed scientific understandings of Earth systems.[347] In this final section, I will look at a specific type of satellite analysis (that using InSAR or interferometric synthetic aperture radar) and a specific environmental phenomenon (the Kobe or Great Hanshin Earthquake of 1995) as a window through which to challenge notions of scientific progress towards objective truth.

One common way to think about objectivity is tied to a notion of a "view from nowhere."[348] It is through escaping our limited subjective perspectives and looking at phenomena disinterestedly that we can understand what the world is really like, and scientific methods offer the most promising way to do so. Decades of scholarship across many disciplines

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[346] See "The Boy Who Cried, 'Wolf!' or Why a Community-based Alert System is a Good Idea." *Safer Cities 18: Case Studies on Mitigating Disasters in Asia and the Pacific*. Asian Disaster Preparedness Center. 2006.
[347] National Research Council. *Earth Observations from Space* catalogs these achievements. For a brief summary, see p. 1-7.
[348] For a thorough philosophical treatment of this concept and its implications, see Thomas Nagel. *The View from Nowhere* (New York: Oxford UP, 1986). For a useful overview of debates and ideas on the topic, see Julian Reiss. "Scientific Objectivity." *Stanford Encyclopedia of Philosophy*. 25 August 2014. https://plato.stanford.edu/entries/scientific-objectivity/.

has challenged the notion that such a view is possible. In her classic essay "Situated Knowledges," Donna Haraway, seeking a feminist epistemology, refers to such a notion of objectivity as an illusion, a "god trick" that hides the power relations and privileged subjectivities that go into scientific knowledge production. All views are inescapably "from somewhere." She notes the ironic metaphoric appropriation of our sense of vision in positing the view from nowhere. In reality, vision is always embodied and tied to the physical processes that condition its possibility.[349]

However, Haraway also suggests that our particular and embodied "situated knowledges" are not necessarily organic. Technology too can be part of our situated perspectives. In fact, technological systems help us understand why all perspectives are limited:

> The "eyes" made available in modern technological sciences shatter any idea of passive vision; these prosthetic devices show us that all eyes, including our own organic ones, are active perceptual systems, building on translations and specific ways of seeing… There is no unmediated photograph… only high specific visual possibilities, each with a wonderfully detailed, active, partial way of organizing worlds.[350]

Haraway briefly even mentions satellites' "eyes" as an example of the situated epistemic perspectives of technological systems.[351] It is not merely human subjectivities that situate scientific knowledge, but the coupled system that makes up the human-satellite mind, situated in ways that ultimately reified a notion of "nature," that failed to grasp important dimensions of reality that grounded perspectives could reveal.

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[349] Donna Haraway. "Situated Knowledges: The Science-Question in Feminism and the Privilege of Partial Perspective." *Feminist Studies*, Vol. 14 No. 3 (1988). 575-582, 590. For a useful summary of Haraway's major points and their influence on later materialist feminist approaches, see Monica Rogowska-Stangret. "Situated Knowledges." *New Materialism: How Matter Comes to Matter*. 22 March 2018. http://newmaterialism.eu/almanac/s/situated-knowledges.

[350] Donna Haraway. "Situated Knowledges," 583.

[351] Ibid, 582-583.

The Kobe Earthquake hit the namesake city on January 17th, 1995 with a strength of 7.2 on the Richter scale. The damage the quake caused, especially to the many wooden buildings which caught fire and their residents, was immense, on a scale Japan had not seen since the Kanto Earthquake which devastated Tokyo in 1923. By midnight, more than 1,500 had died, and the destruction would have lasting effects on the city's economic development. On a broader national level, the earthquake's legacy was felt deeply as many lost trust in the central government due to its negligent, bureaucratically handicapped response. This loss of credibility also helped to spur the development of a stronger civil society in Japan, as many around the country filled the aid vacuum left by the government with volunteer efforts.[352]

In the wake of reconstruction efforts, a handful of Japanese researchers sought to understand how earthquake damage was distributed, as well as the underlying mechanics of tectonic displacement, through novel methods developed a few years prior in Europe. In 1993, the journal *Nature* released its 364th volume with a cover depicting a satellite analysis of the 1992 Landers Earthquake in California. This was, as the bold letters of the title announced, "The image of an earthquake."[353] The image was produced by Didier Massonnet and colleagues using the ERS-1 satellite, taking advantage of a number of principles. First, as they put it: "although most geodetic techniques require a surveyed network to be in place before the earthquake, satellite images, when collected at regular intervals, can capture co-seismic displacements without advance knowledge of the earthquake's location."[354] Thus, Earth-space provided something of a permanent observation network.

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[352] See David W. Edgington. *Reconstructing Kobe: The Geography of Crisis and Opportunity* (Vancouver: UBC Press, 2010). 1-11; Sorensen. *The Making of Urban Japan*, 295-296.
[353] See National Research Council. *Earth Observations from Space*, 95-96.
[354] Didier Massonnet et al. "The Displacement Field of the Landers Earthquake Mapped by Radar Interferometry." *Nature*, Vol. 364 Issue 6433 (1993). 138.

The regular, homogenous collection of data allowed, secondly, for the use of interferometric techniques, meaning that two images, taken before and after the disaster, can be compared to analyze changes in one location over time. Specifically, InSAR analysis of earthquakes is used to measure crust movements due to geologic activity. Basically, the satellites do this through transmitting energy to the surface, which is then backscattered as it bounces back off and is received again by the satellite. When this is done at two different times, differences in the scattering patterns reveal surface changes. Finally, SAR satellites' use of microwave radiation as a transmission medium has the added benefit of being relatively immune to a range of atmospheric conditions like clouds and rain that otherwise would botch the scattering patterns. As Massonnet and his team showed in 1993, these generalized measurements of surface displacement could match on-site ones fairly closely.[355]

Four years later, Shinzaburo Ozawa and others applied these same techniques to measure crust deformation resulting from the Kobe Earthquake and got similarly strong matches with field surveys. The next year, Chinatsu Yonezawa and Shoji Takeuchi used InSAR analysis again, pointing to the extent to which building destruction caused by the earthquake led to backscattering differences. Here, I want to narrow my focus on one 2000 paper by Masashi Matsuoka and Fumio Yamazaki, who collaborated to apply InSAR techniques to analyze later earthquakes as well.[356]

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[355] Ibid, 140. For a brief and accessible explanation of InSAR analysis, see "Interferometric Synthetic Aperture Radar." Geodetic Techniques. *Geoscience Australia*. http://www.ga.gov.au/scientific-topics/positioning-navigation/geodesy/geodetic-techniques/interferometric-synthetic-aperture-radar.

[356] Shinzaburo Ozawa et al. "Synthetic Aperture Radar Interferogram of the 1995 Kobe Earthquake and its Geodetic Inversion." *Geophysical Research Letters*, Vol. 24 No. 18 (1997). 2327-2330; Chinatsu Yonezawa and Shoji Takeuchi. "Detection of Damaged Built-up Areas by the 1995 Hyogoken-Nanbu Earthquake Using ERS-1/SAR Intensity Images." *Journal of the Japan Society of Photogrammetry and Remote Sensing*, Vol. 37 No. 4 (1998). 57-61; Masashi Matsuoka and Fumio Yamazaki. "Interferometric Characterization of the Areas Damaged by the 1995 Kobe Earthquake Using Satellite SAR Images." *Proceedings of the 12th World Conference on Earthquake Engineering*. Paper No. 2141. 2000; "Use of Interferometric Satellite SAR for Earthquake Damage Detection." *Proceedings of 6th International Conference on Seismic Zonation*. 2000. For their more recent work, see

In their paper, Matsuoka and Yamazaki look at decoherence between backscattering patterns received before and after the earthquake. Going further, they look at patterns relative to the amount and types of damage done. Following Yonezawa, they note how collapsed or damaged buildings have reflectance patterns different from built-up areas. Overall, their goal is to analyze the distribution of damage caused by the earthquake by comparing reflectance patterns in areas that underwent varying degrees of destruction to their pre-earthquake patterns. In doing so, their work was meant to further aid in reconstruction efforts.

Both in their 2000 paper and earlier InSAR research, several important ideas emerge, sometimes only implicitly, that point to the ways the "natural disaster" of the Kobe Earthquake was constructed from a "view from somewhere." The situated epistemology of InSAR analyses worked to both construct and reconstruct the nature of the disaster. One powerful aspect of subjectivity arises from the time-frame within which the disaster is located. As Matsuoka and Yamazaki write, earlier InSAR analyses were hampered as their post-event images were taken much as four months after the earthquake. As a correction, they select images from as close as a year prior to and 20 days after the event. In doing so, they effectively cordon off the boundaries of what defines the "event" of the earthquake in the first place. In selecting the 1994 image as a "pre-event" comparison, they effectively normalize the state of affairs existing at that time, which in result is imagined as "normal" time during which disaster did not exist.[357]

The same authors fall back on this notion of normalcy more strongly in a later 2010 analysis, where they write that "earthquakes that have caused large-scale damage… remind us of

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"Comparative Analysis for Detecting Areas with Building Damage from Several Destructive Earthquakes using Satellite Synthetic Aperture Radar Images." *Journal of Applied Remote Sensing*, Vol. 4 No. 1 (2010). 041867-041867-14

[357] Matsuoka and Yamazaki. "Interferometric Characterization," 1-2.

the importance of making quick damage assessments in order to facilitate the resumption of normal activities and restoration planning."[358] Note the terms "resumption" and "restoration." Such language implies that pre-event relations are desirable and in need of being reinstated following the disaster of the earthquake. Most importantly, bounding the beginning of the disaster as they do effectively equates the disaster of the earthquake with a narrow span of time during which geological events took place.

However, the state of the built environment and social hierarchies within are always part of what makes an earthquake affect the physical and social geography as it does. For example, older wooden architecture in the central urban area was easily destroyed during the quake, and it is no further coincidence that these homes were largely occupied by the elderly and disadvantaged. The disaster cannot be bounded in the past so quickly, as doing so is a way to socially construct the disaster to reaffirm the desirability of social affairs prior to the event and ahistorically locate those relations outside the causal network that made much of the disaster disastrous in the first place. In reality, the earthquake-disaster is what might be called, via Timothy Morton, a "hyperobject," whose temporal and spatial dimensions are so expansive and vague that they defy our ability to effectively fit it into our standard conceptions of how to define a "thing" in the first place.[359]

As the obvious social dimensions of the disaster demonstrate, there is something misleading about referring, as these authors and others do, to the earthquake as a "natural disaster." Of course, they likely intended little by the use of this phrase given its familiarity, but it nonetheless can reflect something about the way people often think about different kinds of

[358] Matsuoka and Yamazaki. "Comparative Analysis," 1.
[359] See Timothy Morton. *Hyperobjects: Philosophy and Ecology after the End of the World* (Minneapolis: Minnesota UP, 2013).

disasters. For example, while in Japan, I took a course on Japanese politics, during which the professor explored the executive administrations of each prime minister during the 1990s. As he explained the failures and successes of the Tomiichi Murayama administration, which was in power at the time of the earthquake, he blithely noted how of course the earthquake, compared with other economic and political problems, was not Murayama's fault. While this judgment seems intuitive, it separates the natural and the social all too readily. The geography of Kobe, the social and political relations tied to it, and the central government's notoriously weak response are all certainly elements that transformed the earthquake from a neutral geologic occurrence into a *disaster*.

The image produced on the front of *Nature*, the "image of an earthquake," implicitly locates the disaster, along with the analyses of Ozawa later, within "nature" and not "society." The earthquake is a geologic event associated with ground deformation, which *subsequently has effects* on people and their environment. While Matsuoka and Yamazaki are measuring changes to the built environment, rather than the crust, they are clear that "building damage was focused on as a form of earthquake damage in this study."[360] The earthquakes themselves, within this and other studies, are implicitly equated with events of natural history, tectonic shifts which "hit" cities and themselves cause disasters with their sheer potency.

In order to understand how the satellite's gaze constructed the earthquake-disaster as a temporally located, natural event out of a hybrid hyperobject, we must move beyond a social constructivist picture towards what Karen Barad refers to as a "material-discursive" account. It is not enough to say that reality is socially constructed; we need more robust accounts of how matter and discourse interact to create history. While it is by now almost habitual to think of

[360] Matsuoka and Yamazaki. "Interferometric Characterization," 2.

discourse as "productive," of language and concepts as enabling and constraining the kinds of things historical actors can think about and do, such one-sided emphasis on discourse blinds us to the objects around us.

To push against this perspective, Barad, inspired by Niels Bohr's "philosophy-physics," introduces a notion of *material-discursivity*. "For Bohr," she writes, "apparatuses… are the local physical conditions that enable and constrain knowledge practices such as conceptualizing and measuring; they are productive of (and part of) the phenomena produced." As she emphasizes, it is not "merely that discourse is 'supported' or 'sustained' by material practices." Rather, "the issue is the conjoined material-discursive nature of constraints, conditions, and practices."[361]Applied to InSAR analysis, a material-discursive approach allows a more holistic understanding of how social construction is as much a matter of material practice as it is of abstract ideology. In giving such an account, the seeming dichotomy between materialist and constructivist schools of thought can be bridged. Marxist kinds of critical realism, acknowledging both a material base as well as a socially constructed "ideology" in some ways accord with this line of reasoning. However, rather than reducing materiality to large sets of hegemonic economic relationships, materiality can be seen as more constant and fluid, influencing and enabling certain social constructions in contingent ways.

The material and spatial nature of satellites in Earth-space did, as suggested, constrain and enable the ways that the earthquake could be constructed. While scientists themselves might imagine the earthquake-disaster as a hyperobject vaguely bounded in time, the satellite could not. As noted earlier, InSAR analysis was adopted partially because satellites regularly took images of the surface at set intervals which could be compared interferometrically in hindsight. For

[361] Barad. *Meeting the Universe Halfway,* 146-152.

interferometric analysis to be feasible in the first place, pre- and post-event images were needed, and the temporal locations of those images were determined in part by what kinds of satellite images were available to use. If the time-frame of the disaster was constructed, it was not constructed merely according to the scientists' whims. Rather, the construct was situated in the cosmic geography of the near-Earth orbit.

Likewise, the same epistemic fundamentals described earlier, synopticism and quantification, enabled certain kinds of empirical claims and constrained any ability to see certain other aspects of reality. The sheer magnitude of the spatial scale used mean that satellite images turn complex and heterogeneous geographies into "standardized spaces."[362] Pixels in InSAR images did not correspond perfectly to points of space, and as Matsuoka and Yamazaki describe, a good deal of homogenization and idealization went into fitting images together before decoherence patterns could be discovered. More importantly, as they make clear, theirs is a "quantitative approach."[363] Spaces with all manner of different social meanings were reduced to their radar reflectance quantities. As Monica Brannon puts it:

> "… a perception that privileges a mechanical objectivity over the narrative, 'on the ground,' social experience; this way of seeing ultimately reduces spaces to renderings of mathematical measurements… While seen by the public as true depictions of reality… they are visual outputs that are representational forms relying on quantitative measures and calculations, codes and algorithms that turn spaces of nature and built environments into pixilated, scalable, scrollable merged and seamless globes… telling a particular narrative that is mechanically organized and modeled to represent natural space, but these images are in fact interpreted data sets that have been manipulated to produce simulated models of territories.[364]

This "particular narrative," situated as it is across Earth-space, cannot be explained simply be appealing alone to the scientists' subjectivities. In a very real sense, the satellite saw

[362] Monica M. Brannon. "Standardized Spaces: Satellite Imagery in the Age of Big Data." *Configurations*, Vol. 21 No. 3 (2013). 271-299.
[363] Matsuoka and Yamazaki. "Interferometric Characterization," 2, 5.
[364] Brannon. "Standardized Spaces," 275-277.

what it could see. Likewise, the satellite-human system saw what it could see, namely a quantitative depiction of reality, bounded in systematic ways. It was this material-discursive construction of the earthquake which reified an "image" of the earthquake as a "natural disaster" and helped fit it into an ontology that sharply distinguished the social and the natural: "humans are generally not seen in satellite images."[365]

**The Ontology of Earthquakes**

One of the most important issues that emerged in the preceding section is a question regarding what an earthquake really *is*, or, what *kind* of thing an earthquake is. In other words, the ontology of earthquakes. The satellite apparatus, in Barad's terms, is a "boundary making practice" that "enacts cuts" within phenomena, such as rending nature and society apart.[366] InSAR analysis of the Kobe Earthquake implicitly upheld a separation between society and nature as it configured the multi-layered event as a "natural disaster" located in tectonic motions (cause) that shook society (effect).

This ontology, wherein earthquake-disasters are categorized as geologic events that have an effect on society only after the fact, is one that is familiar. A "grounded" ontology of the Kobe earthquake, however, looks very different. David Edgington's social geography of the disaster gives a sense of what this ontology looks like. Edgington describes Kobe's urban patterns as a "geography of crisis" that systematically made vulnerable those on society's margins; the poor, elderly, and disabled. This "highly uneven social geography… played a role in how disaster risks and outcomes were distributed throughout the city." The western part of the city which was hit the hardest was built up with underdeveloped wooden houses and narrow roads, inhabited by

[365] Ibid, 279
[366] Barad. *Meeting the Universe Halfway*, 147-148.

those marginalized groups put in harm's way. In short, "geography and spatial relationships were implicated in the Kobe crisis…it is a truism that earthquakes are only a disaster if there are vulnerable people in the way."[367]

A grounded ontology, from the perspective of those vulnerable groups, does not admit of the society-nature cut enacted by the satellite gaze. The disaster for a poor, elderly or disabled resident living in western Kobe in a ramshackle wooden house was clearly not purely natural, the effect of very recent geologic events, but a hybrid event revolving around harder to pin down social relations and temporally spread out historical developments. Haraway describes a method of "preferred positioning" whereby a "feminist objectivity" can be obtained between the view from nowhere and pure relativism. Subjugated groups, like hegemonic ones, are not "innocent" and have no claims to objective knowledge. However, their partial truths, seen "from below" are often more relevant standpoints precisely because their positioning and viewpoint in relation to the powerful grants them an epistemic power as they have this critical experience to draw on. By listening especially to subjugated standpoints, we can work to piece together an objective worldview that is not blinded by a pretense of impartiality, but gains its power precisely due to its ethical commitment to being partial in how it listens to, deconstructs, and challenges different perspectives. Doing so allows one to fully embrace a plurality of heterogeneous perspectives woven together to create what science should aim to do: create "better accounts of the world."[368]

If preferred positioning pushes us to give a certain, albeit critical, credence in grounded ontologies of earthquakes, the question becomes what those viewpoints are telling us about the kind of thing the Kobe Earthquake was. One framework, put forth by Barad, imagines events like the earthquake-disaster to be "intra-active" phenomena. By coining this phrase, Barad seeks to

[367] Edgington. *Reconstructing Kobe*, 49-52.
[368] Haraway. "Situated Knowledges," 583-590.

avoid the semantic challenges of the phrase "interaction," which implies that the interacting objects have independent agencies that come together to produce phenomena. Rather, intra-action puts the phenomenon, the disaster of the earthquake, ontologically-prior.[369] Within the earthquake-disaster, then, are not distinct forces acting together, but radically hybridized things that are internal to the phenomenon itself.

Given this, one might suggest that the social and physical geography of Kobe intra-acts with the seismic activity. Both do not merely contribute to the disaster, but rely on one another to produce it. As Edgington's analysis shows, the seismic activity required a geography of crisis to gain the potency it did. Likewise, however, one might say that Japanese urban planning in its complex dimensions cannot be understood historically without taking into account the seismicity of the archipelago. As one group of authors recently put it: "past 'natural hazards' have shaped the 'natural bounties' such as relatively flat lands and alluvial plains of today… society coevolved with these geological forces."[370] To discuss the nature of Japanese urbanism without discussing how natural disasters like earthquakes shaped policy, popular behavior, and government responses, and likewise how those social factors shaped earthquake-disasters, is to ignore the deep intra-activity of the Kobe Earthquake.

Other feminist scholars working on materialist lines have come to similar conclusions. Nancy Tuana, for example, describes one natural disaster, Hurricane Katrina, as a case of "viscous porosity." Hers is an "interactionist ontology": "Katrina is a natural phenomenon that is what it is in part because of human social structures and practices." Katrina was not merely a social disaster produced through racialized hierarchies and anthropogenic climate change, but

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[369] See Barad. *Meeting the Universe Halfway*, esp. 139-141.

[370] See Abhik Chakraborty and Kuniyasu Mokudai. "Challenges for Geoconservation in Contemporary Japan." *Natural Heritage of Japan: Geological, Geomorphological, and Ecological Aspects*. Ed. Abhik Chakraborty et al (Cham: Springer International, 2018). 144. This quote refers to earlier work by Mokudai.

was also clearly also not purely a natural disaster: "we cannot sift through and separate what is 'natural' from what is 'human-induced.'" Interactive ontologies require that we think of agency as something that emerges from the relations between actors, rather than from anyone in particular.[371]

Also important to Tuana's argument, however, is that the variable *extents* of human and natural influence are still explicable, which is why she rejects the term "fluid" in favor of "viscous" to imply that while the boundaries are amorphous, society and nature do not flow into each other so easily. The variable extents must be recognized in disaster events, both to avoid thinking of nature as inert and passive as well as to enable social justice movements to hold human actors responsible. Barad's intra-active ontology seems to conflict with the materialist "object-oriented" perspectives of Graham Harman and to some extent LeCain. In Chapter 1, I focused on how material objects like concrete have power in history that must be located within those objects, as part of their "thing-power." However, intra-activity suggests that things do not have power because the agencies of urban form or seismic activity are not distinguishable. Tuana's account offers a way out of this conundrum by allowing agency to emerge out of relationships, while also allowing different factors to have distinguishable "extents of influence."[372]

However, exactly how these extents function and work together is vague. In line with this desire to take into account the power of nature while also giving a relational ontology its due, one can adopt a more Aristotelian approach to causation. For Aristotle, to understand what a thing is, its essence, required an understanding of its causation, and the causes of any

[371] Nancy Tuana. "Viscous Porosity: Witnessing Katrina." *Material Feminisms*. Ed. Stacy Alaimo and Susan Hekman (Bloomington: Indiana UP, 2008). 190-193.
[372] Ibid, 193-194.

phenomenon for Aristotle were four-fold: material, formal, efficient, and final: the *material* cause the matter from which the effect is structured, in the case of a sculpture for example, the bronze of a statue; the *formal* cause the form or shape which that matter is structured around, i.e. the shape of a man; the most familiar *efficient* cause that which drives change, i.e. the artist; and the *final* cause the *telos*, the end towards which the effect is intended, i.e. the beauty of the art.[373]

Rather than thinking that causation merely lies in the efficient mover of events, that pushes inert objects into place, this approach interprets these objects as vital characters in the process of "bringing-forth" events, even without taking on board the final, teleological cause.[374] In 1995, the Kobe Earthquake was only "caused" by seismic activity in a narrow sense of the term. If we focus additionally on the material and formal cause, the *physical* structure of the shaking urban fabric as well as the social geography that *shaped* the distribution of earthquake damage can be understood as important causes of the earthquake-disaster. Moreover, this unification of causes does not entail that we deprive either the seismic jolts or the things and social relations they shook of their own power. Rather, for the disaster of the earthquake to be brought about required seismic activity to act *with* a social and physical context that gave potency to the tectonic shifts. Understanding the earthquake, if explained as a disastrous event made up of causes, requires a deep appreciation of the multiplicity of causes that brought-forth the earthquake.

Moreover, such an approach can be especially appreciated from the fragmentary approach to objectivity favored by Haraway. The deeply quantitative knowledge of the

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[373] See Aristotle. "Physics." Trans. S. Marc Cohen. *Readings in Ancient Greek Philosophy: From Thales to Aristotle*. 5th Edition. Ed. S. Marc Cohen et al (Indianapolis: Hackett, 2016); Andrea Falcon. "Aristotle on Causality." *Stanford Encyclopedia of Philosophy*. Last revised 11 March 2015. https://plato.stanford.edu/entries/aristotle-causality/.

[374] The terminology of "bringing-forth" here I borrow from Martin Heidegger's interpretation of Aristototelian causation. "The Question Concerning Technology." *The Question Concerning Technology and Other Essays*. Trans. William Lovitt (New York: Garland Publishing, Inc., 1977). 6-12.

mechanics of an earthquake given by InSAR remote sensing is a set of partial truths that can be supplemented by Edgington's geographical analysis. Neither view is impartial or comprehensive; Earth-space and grounded ontologies both have value precisely because they are situated in unique ways. In writing the history of the Kobe Earthquake, all aspects of its causal identity, both in isolation and as a unified, complex whole must be attended to. On one level, the idea that earthquakes are social disasters as well as natural seems trivial, something that is well-known. However, my goal here is to offer a new conceptual apparatus for analyzing the hybridity of earthquake-disasters because natural disaster language constrains our ability to understand and describe them.

**Environmental Justice and Semantic Incommensurability**

Kuhn writes that "proponents of competing paradigms practice their trades in *different worlds"* (italics mine).[375] Embedded here is the kind of semantic incommensurability evident in the Copernican's inability to conceptualize a Ptolemaic "planet" within a Copernican *conceptual vocabulary*. The same kind of incommensurability can be seen between an interactionist and naturalistic ontology of earthquakes in the way each respectively defines "earthquake" as a natural disaster or socio-natural one. For the latter, the term "earthquake" refers to both a seismic event and a subsequent disaster. Emerging from this twin reference is the concept of "natural disaster." Such a conceptual vocabulary was evident in the way InSAR analysts described the Kobe Earthquake, as a temporally collapsed event whose potency was entirely describable with reference to natural events. In Aristotelian terms, the earthquake-as-disaster is equated with its efficient cause.

[375] Kuhn. *The Structure of Scientific Revolutions*, 143-158

However, in the interactionist Aristotelian approach described earlier, there is a very different conceptual vocabulary that does not admit the idea of natural disaster into its framework. The earthquake-as-disaster is only partially explicated by the efficient cause, and a total description of the event relies on an array of formal and material causes as well. Just like moons and suns have no correlated category within a Ptolemaic vocabulary, material and formal causes have none in what can be called "natural disaster language." This is not to say that InSAR scientists could not explain the social contributions to the Kobe Earthquake. However, to do so would require them to reach outside of the natural disaster language in order to rend apart the co-reference embedded in its conceptual vocabulary.

According to Kuhn, his notion of incommensurability arose from his own frustration in trying to understand Aristotle's science, which could only suggest that Aristotle was a terrible scientist before he realized that Aristotle simply could not be understood in the frameworks of modern physics.[376] By light of a traditional progressivist historiography, older premodern theories of disaster in Japan and elsewhere look similarly quaint and superstitious.

Globally, humans before the early modern period often linked social norms closely to natural disasters. In China, the "mandate of heaven" was given to rulers as a condition for them maintaining the prosperity of the realm. Disasters, whether they be earthquakes, floods, famines, or uprisings, all reflected poorly on the rulers. This idea influenced Japanese disaster theories as well, and ordinary people often understood the state of political affairs and moral norms as background causes to natural disasters like earthquakes.[377]

As Gregory Smits writes:

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[376] Bird, "Thomas Kuhn."

[377] See Andrea Janku. "'Heaven-Sent Disasters' in Late Imperial China: The Scope of the State and Beyond." *Natural Disasters, Cultural Responses: Case Studies toward a Global Environmental History*. Ed. Christof Mauch and Christian Pfister (Lanham: Lexington Books, 2009). 233-264

> Despite widespread agreement on the basic physical mechanisms that produced earthquakes, these mechanisms were only the proximate cause of shaking… A lack of clear boundaries between natural and social phenomena encouraged a tendency to view these realms as interconnected.[378]

Moral degeneration, often in the form of indulgent overconsumption or a failure to follow Buddhist teaching was often causally tied on a cosmological level to earthquake-disasters. One Buddhist thinker, Nichiren, argued in 1260 that:

> When people turn their back on the True Law and embrace the Wicked Law, a variety of problems plague a country. These problems include abnormalities of the sun and moon, abnormalities of the stars, fires, floods, windstorms, droughts, external military invasions, famine, warfare, and epidemic disease.[379]

The incommensurability is apparent when comparing modern mechanistic earthquake theories with those older philosophies. An older disaster-theory that laid the blame on political authorities for earthquakes seems incompatible with modern assumptions. Describing the earthquake as a natural disaster would make little sense in a world where the social and political ills of the time are directly responsible. Likewise, older texts that place blame on rulers for natural disasters only seem so strange and superstitious because we are imagining that the blame for distant geological events is being placed on human social relations. Of course, we should not romanticize a primitive Japanese harmony with nature here. Acknowledgement of social causation did not mean political success in achieving any social justice. Political authority and natural forces were often as antagonistic in medieval Japan as they are today, and, rather than romanticizing the relationship, these texts bring this contention to the forefront.

It is not merely that one paradigm needs to translate the other, such that a natural-disaster theorist could reread these theories keeping in mind that when they said "earthquake" they meant

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[378] Gregory Smits. *Seismic Japan: The Long History and Continuing Legacy of the Ansei Edo Earthquake* (Honolulu: Hawaii UP, 2013). 72.

[379] Ibid, 40. This text is paraphrased from Nichiren's *Treatise on Securing Peace for the Country* by Smits.

social causes as well. This lack of easy translatability arises for two reasons. First, it is not merely that the two theories assign different terms to concepts apparent in either vocabulary. The natural disaster theorist, while speaking in natural disaster language, cannot formulate a socio-natural definition of "earthquake" using those concepts because they reduce earthquake-disasters to their efficient causal constituents. It is not just semantics that bar the way, but conceptual schema that carve up the world in incompatible ways; in order to comprehend the older vocabulary, the natural disaster theorist would have to use their *concepts*, concepts that are importantly not linguistically, but only theoretically constrained.

Furthermore, as Kuhn argues, paradigmatic concepts are defined through a "local holism," meaning that adjacent concepts are interlocked in their meanings, further constraining translation attempts that seek a one-to-one translation.[380] Natural disaster language is not just the term "natural disaster" and its implications, but a whole set of concepts. Terms like "restoration," "mitigation," and "disaster preparedness," all point towards a background ideology wherein earthquake-disasters act upon society from without. While it is commonplace to blame authorities for failing to mitigate disasters or *respond* to them, this kind of modern blame is simply not radical enough. Socio-economic structures are almost always in the foreground of the causal chains that lead to "natural" disasters in the first place.

In theorizing earthquake-disasters as fundamentally political phenomena, older theories allowed people to sensibly blame corrupt authorities for disaster and provided an impetus to revolt or otherwise revolutionize the state of social affairs in the aftermath of disasters. This older knowledge gave the populace a framework with which to use the effects of natural disasters as tools for social justice, giving them concepts through which to seek greater control

[380] Sankey. "Taxonomic Incommensurability," 9.

over the interactions between society and nature. Absent this hybrid understanding, the society-nature separation that plays such a large role in modern disaster theories offers little political motivation. If not reflective of social circumstances, natural disasters do not provide the revolutionary impetus for political change. Disasters should not motivate a desire to resume or restore pre-event normal time, but should spur the question: what went wrong, and how should we change?

One assumption of the progressivist notion of modernity is that science has given us better images of nature over time. Kuhn's notion of paradigms directly challenges this history, as it implies that there are insurmountable difficulties in assessing what it meant by "better" and in comparing those images to one another. Unlike some of his more radical followers, Kuhn was never an outright relativist. However, paradigm shifts can mean that valuable past insights or explanations are lost in transition, a so-called "Kuhn-loss."[381]

Environmental justice, as a modern movement that seeks foremost to see how socio-political inequality is correlated to disproportional environmental harms, seeks to recover this loss. With regard to natural disasters, Priscilla Ward writes with this in mind:

> The adjective 'natural' obscures human contributions to environmental hazards and the conditions that transform them into disasters...the metamorphosis illustrates the power of language to obviate human agency and structural inequities and to place a hazard into a context in which the conditions of its possiblility and its impact are temporally collapsed, folded into a single event rather than a process.[382]

Ward's concerns reflect the incommensurability between seeing disasters as natural versus hybrid events. Moreover, her concerns with the social causation of disaster are far more in line with premodern theories than with modern ideas. Of course, the two are very different

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[381] Bird, "Thomas Kuhn."

[382] See Priscilla Ward. "Natural Disaster." *Keywords for Environmental Studies*. Ed. Joni Adamson et al (New York: NYU Press, 2016). 148-150.

methodologically and in content. However, they live the same "world" where, at its thinnest level, earthquake-disasters can be ascribed to social relationships.

Although medieval Japanese social norms are often alien to us today, they conceived of a world wherein moral shortcoming could lead to disaster, the same *kind* of world Priscilla Ward theorizes. In fact, some views were more alike than we give credit to. For example, in the Edo period, Kaibara Ekken, sometimes termed the "Japanese Aristotle" for his empirical philosophy, wrote that "if vast material wealth is collected in one place and not permitted to benefit and enrich others, disaster will strike later."[383] While his views here are tied to a Buddhist cosmology of energy concentrations and flows, some concepts in these two worlds (wealth inequality as a cause of natural disaster) may not always be so structurally at odds. If environmental justice is a movement that seeks to bring a greater measure of control over social-nature interactions to marginalized groups, the ontological framework required to make sense of this motivation is not one that has gotten clearer over time. Rather, as modern scientific theories of disaster became prevalent, the interactions between society and nature were hidden in a paradigm that regarded earthquake-disasters as natural events.

**Conclusion: Hypocognition and Hope**

In my home state of North Carolina, the onslaught of Hurricane Florence in the fall of 2018 while I was writing this thesis served as a reminder of the deeply troubling relationship

[383] Smits. *Seismic Japan*, 72. For background on Ekken, see James W. Heisig et al (ed.). *Japanese Philosophy: A Sourcebook* (Honolulu: Hawaii UP, 2011). 360-361. As an aside, Smits explicitly disagrees with Gregory Clancey concerning the 'levelling effect' of natural disasters. Writing about the Ansei Earthquake of 1855, Smits argues that the disaster did not respect socioeconomic hierarchies and often affected those with more status more dramatically for entirely contingent reasons. However, the levelling effect of natural disasters has changed over time. As the nature and effects of disasters become identified and technological solutions are discovered, those with higher privilege gain a greater ability to insulate themselves, creating an uneven geography of disaster. For a review of some relevant literature on this topic, see Adam Rome. "What Really Matters in History: Environmental Perspectives in Modern America." *Environmental History* Vol. 7 No. 2 (2002). 308.

between people, nature, and power. North Carolina, often considered to be the fount of the environmental justice movement in the US, was hit by Florence in September, but as Ward argues disasters are not a single event but a process.[384] Particularly on the coast, where the hurricane hit strongest, overflowing coal ash pits and hog manure lagoons threatened the health and well-being of primarily black communities. Just as with the floods I had read about daily a couple of months prior, Florence was as much a social disaster as it was a natural one. In one article from September, "Mapping Environmental Justice in Hurricane Florence's Wake," Brendan Mock provides a geography of crisis in the Carolinas, looking at "eight places [that] have long been vulnerable… without them, we may not have the language, knowledge, and tools to fight environmental injustice in the age of climate change."[385] It is not just that racism made the natural disaster *worse*, or made people *vulnerable to* the natural disaster, or any of these other more common interpretations that one often reads that try to explain social disasters in natural disaster language. Racism was part-and-parcel of what the disaster, as a process, substantially *was*.

In other words, what is needed is a paradigm shift. It is not that our current concerns do not differ from the moral outlooks of many premodern societies, or that we need to abandon scientific worldviews. However, theories that take into account modern science can be constructed in dialogue with older disaster theories that have historically offered a powerful

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[384] For more on North Carolina's key role in the history of environmental justice, see Eileen McGurty. *Transforming Environmentalism: Warren County, PCBs, and the Origins of Environmental Justice* (New Brunswick: Rutgers UP, 2009).

[385] Brendan Mock. "Mapping Environmental Justice in Hurricane Florence's Wake: Mapping Where Environmental Justice is Most Threatened in the Carolinas." *Citylab*. 21 September 2018. https://www.citylab.com/equity/2018/09/mapping-where-environmental-justice-is-most-threatened-in-the-carolinas/570985/. See also Lisa Hymas. "Here's a Hurricane Florence Environmental Justice Story that Media Outlets Need to Tell." *Media Matters for America*. 13 September 2018. https://www.mediamatters.org/blog/2018/09/13/Heres-a-Hurricane-Florence-environmental-justice-story-that-media-outlets-need-to-tell/221293.

source of political impetus. I do not believe my proposal that social factors contribute to natural disasters is revolutionary. Nonetheless, this insight is often undermined by the mainstream rival discourse of natural disasters. Using concepts of incommensurability, older disaster theories, Aristotelian causation, and interactionist ontological philosophies, alternative discourse can be further shored up and conceptualized.

It is tempting to interpret the incommensurability problem we face as a case of what some call "hypocognition," referring to a phenomenon where members of a language group are unable to communicate certain concepts because they lack the words to do so. A similar notion of *linguistic determinism* entails that language constrains and/or enables how someone can think. While this concept has caught on within the humanities and remains implicit in many scholars' work, linguists harbor deep doubts about its efficacy.[386] What is required, in my view, is not a linguistic revolution. Here, I have argued that the language of natural disaster is a powerful window through which to look at patterns of background conceptions about how society and nature are related. As such, I do not believe that our use of natural disaster language and the correlated belief that earthquake-disasters are caused by natural forces is a coincidence, but exactly how these linguistic and conceptual schemes relate is a more complex question.

Whatever the answer may be, I believe that the relationship is contingent rather than necessary. Our concepts are not constrained by our language, and this radical interpretation of linguistic determinism is not what semantic incommensurability need entail. Semantic

[386] While hypocognition seems like a breed of linguistic determinism, I have not found any sources that attests to this, and of course have no expertise myself. For hypocognition, see Harriet Joseph Ottenheimer and Judith M.S. Pine. *The Anthropology of Language: An Introduction to Linguistic Anthropology*. 4th Edition (Cengage: Boston, 2019). 45-46. Linguistic determinism, particularly its more radical "strong" variety, is often used interchangeable with the "Sapir-Whorf Hypothesis." See Bernard Comrie. "Language and Thought." *Linguistic Society of America*. https://www.linguisticsociety.org/resource/language-and-thought; Francis Jeffry Pelletier and Geoffrey K. Pullum. "Philosophy of Linguistics." *Stanford Encyclopedia of Philosophy*. Last revised 1 January 2015. https://plato.stanford.edu/entries/linguistics/. See under "Whorfianism."

incommensurability concerns incompatible sets of *concepts*, but these concepts can be described just as well with any language. Natural disaster language is not the words that make it up, but the underlying meanings that those words are used to get at, and this talk of "language," "translation" and "conceptual vocabulary" need only be figurative analogies. I am not pessimistic about the adequacy of our language to uphold a rapid and radical change in our beliefs about natural disasters; especially with climate change in full force, the lines between society and nature are increasingly becoming vaguer. As Haraway and others make clear, what counts as a "better account of the world" is an ethical question as much as it is an epistemological one. To make sense of the hybrid reality of natural disasters and move towards a more just interpretation, we need a better account, and I am hopeful that in the 21st century we have the context as well as the tools that modernity has often failed to offer to adapt to the relationships around us.

# Innumerable Systems Rolled: Japanese Spaceflight in the 1990s

## Introduction: The History of a Jointless Reality

On July 7th of 2018, I took the train to the Buddhist temple of Zojo-ji in Tokyo, one of the Tokugawa family's old family temples and the main temple of the Pure Land sect within the region. In Western Japan, the floods were continuing to take their toll, and my own sweat and exhaustion alerted me to the oncoming heat wave that would hit Japan in full force a few weeks from then. That night at Zojo-ji, schoolchildren worked to lay out candles on the grounds, leading the way to the main temple, in celebration of the annual Tanabata festival. According to the Chinese-inspired story, Orihime and Hikoboshi (representing the stars Altair and Vega) lived on opposite sides of the Milky Way. After falling in love, Orihime's father forbade the two to see each other, but eventually allowed them to meet once a year on July 7th, crossing a bridge between them across the galaxy. At Zojo-ji, the arrangement of candles is meant to mirror the Milky Way, an object that not only exists in physical nature, but also within the annals of story and myth (Fig. 3.1).[387]

My own experiences that day speak to the irreducible entanglements between natural, social, and technological elements. Of course, the social history of festivals in Japan and the very human attraction to storytelling and communal celebration were vital to those moments, but the very structure of the celebrations was nature-dependent. The celebration itself has some roots in seasonal change and agriculture, and the traditional wish-making done during the festival reflects those origins in pleas for good agricultural conditions. The festival is celebrated through an engagement with the natural world, as wishes are hung on bamboo and, historically, poems are

[387] For a popular synopsis, see "Tanabata - The Story of Two Star-Crossed Lovers." *Japan Suite*. http://www.japan-suite.com/blog/2014/7/6/tanabata-story-of-two-star-crossed-lovers. For more, including information on Zojo-ji, see Shizuka Sakamoto. "Tanabata: The Night When Love Prevails." *Savvy Tokyo*. 3 July 2018. https://savvytokyo.com/tanabata-night-love-prevails/.

written on dew-covered mulberry leaves.[388] Moreover, the stories around which it revolves are made possible due to the experiences that have emerged over time as humans have interpreted and imagined the cosmos above them and what might populate them. In this way, the Tanabata festival is a part of what some have called "astroculture," the cultural history of imaginative human engagement with the very real environment of outer space.[389]

Figure 3.1[390]

[388] For a more academic summary of the nature and origins of the celebration, see Steven L. Renshaw and Saori Ihara. "A Cultural History of Astronomy in Japan." *Astronomy Across Cultures: This History of Non-Western Astronomy*. Ed. Helaine Selin (Dordrecht: Springer, 2000). 398-399.

[389] The term "astroculture" is associated with Alexander C.T. Geppert: "How have human beings used their creative powers to render the infinite vastness of outer space conceivable… astroculture comprises a heterogeneous array of images and artifacts, media and practices that all aim to ascribe meaning to outer space while stirring both the individual and collective imagination." "European Astrofuturism, Cosmic Provincialism: Historicizing the Space Age." *Imagining Outer Space: European Astroculture in the Twentieth Century*. Ed. Alexander C.T. Geppert. 2nd Edition (London: Palgrave Macmillan, 2018). 8. See also Howard E. McCurdy. *Space and the American Imagination*. 2nd Edition (Baltimore: John Hopkins UP, 2011).

[390] Photo taken by myself on 7 July 2018 at Zojo-ji.

Additionally, my own biophysical limitations constrained my participation. As I stood in vast crowds clambering around the lit paths, I was not the only one whose legs ached under the inescapable stress of the physical tolls of a day of endless standing and walking. The food stalls that led the way to the gate were not only artifacts of Japan's culinary identity, but manifestations of basic caloric requirements that visitors required as they made their way to the temple. The candles remaining lit was purely contingent on the clear skies above, a contrast to those rainy July 7ths where celebrations are strained under the lovers' "rain of tears."[391] In weather, food, representations, and embodied experiences, nature "mattered," sometimes in hidden ways as its power was encapsulated in myth.

Technology also mattered that day, and it would be a mistake to imagine the events of that day as an unmediated relationship between human bodies, imaginations, and the natural world. My ability to be there at all that day was enabled by the complex technological assemblages that power Tokyo's famous train networks. Fire burnt according to basic elemental interactions, but its flames were captured and encultured through the use of candles, which took advantage of these natural principles to create a controlled burn suitable for representing the seemingly static stars light years away. More than anything else, photography attests to the powerful mediating role technology played that day, as my own and countless others' eyes met the world through our smartphone screens which both preserved and constructed our experiences on that day. Those photos themselves also captured the hybrid world around us. To take one example, the temple itself was at once the material culture of Japanese religious institutional growth, the physical manifestation of architectural knowledge and technological development,

[391] For a more detailed account of the festival that includes this reference, see the version from well-known Japanophile and story-collector Lafcadio Hearn. "The Romance of the Milky Way." *The Romance of the Milky Way and Other Studies and Stories* (Leipzig: Bernhard Tauchnitz, 1910). 32-33

and a collection of repurposed trees, whose nature both enabled and suggested certain kinds of architecture and constrained what kind of building the temple could be.

Technology too has its own naturalistic and societal origins, even as it exerts influence over their domains. Concerning the connections between the human-built environment of San Francisco and the primitive natural one of Yosemite Park, Lawrence Culver notes how the former city, from John Muir onwards, "created a hunger for nature" as it helped to catalyze early preservationists. He concludes his essay with a note on the nature of photography and the photography of nature:

> This changeable city has most recently reinvented itself once more, this time not as a city of gold, but of silicon, as the fabled orchards of the Santa Clara Valley gave way to Apple and Silicon Valley. Rare earths and metals from around the world are assembled by workers in China and Mexico into phones, laptops, and tablets, with glowing pixels that reproduce in beautiful detail the tourist photos taken in Yosemite. The city and the valley are not opposites. San Francisco and Yosemite are inextricably bound, one to the other. If we can create a worldview that encompasses both—the natural environment and the built one, the human and the natural, the city and the valley—then we can see the world whole, perhaps for the first time.[392]

In this final chapter, it is this vision of the "world whole" that will play the powerful role of deconstructing the grand narrative of humans using technology to control nature over time. The very basis of this myth relies on providing and protecting set roles for these three notions: humans, technology, and nature. What I seek to demonstrate here is that these three categories do not, as it were, carve the world "at its joints," mirroring the way that reality is really structured.[393] Rather, they create a certain kind of historical construction, one that gives a firm analytic basis for credence in this grand narrative.

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[392] Lawrence Culver. "Confluences of Nature and Culture: Cities in Environmental History." *Oxford Handbook of Environmental History*. 568.

[393] The phrase "to carve nature at its joints" originates from a passage in Plato's *Phaedrus*: "the second principle is that of division into species according to the natural formation, where the joint is, not breaking any part as a bad carver might." Plato. *Phaedrus*. Trans. Benjamin Jowett. *Project Gutenberg*. Last updated 15 January 2013. http://www.gutenberg.org/files/1636/1636-h/1636-h.htm#link2H_4_0002. Since, the phrase has become

In reality, these three do not merely interact with each other; they blend together and co-create each other and the world, emerging as a seamlessly holistic history. In rewriting the history of Japanese spaceflight during the 1990s as holistic rather than partitioned into distinct categories, the events that make up the timeline are all revealed to be irreducibly rooted in the relationships between society, nature, and technology. The goal of this chapter is to reimagine three of these key historical events as deeply hybrid events wherein these three categories fade as they collapse into the complex mesh of reality. If humans, technology, and nature do not really exist as discreet agents, instruments, and objects, then the view of one active human agent interacting with another passive object to exert power over a third becomes untenable.

While the previous two chapters took the approach of following long histories of scientific or urban developments over decades and centuries, this last chapter is both shorter and narrower in its foci, and more impressionistic and narrative in its structure. Each of these three events will be understood as emerging through the *relational* agencies of society, nature, and technology, rather than through any discreet acts of individuals. While individual people and objects may have unique properties that make a difference in the world, like the "thing-power" of concrete, they only enact change, and thus become historically significant, through their embeddedness within a hybrid universe, the "mesh," or the "actor-network."[394] In other words, while properties and potential may be localizable to individuals, *agency*, what one can think of broadly as the power to make change, to act in the world, and to *cause* things in the multidimensional Aristotelian sense, is relational.

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shorthand for a way of thinking a kind of scientific realism whereby the categorical divisions in scientific theory accurately reflect the "natural kinds" that exists in reality. See Joseph Keim Campbell et al (ed.). *Carving Nature at Its Joints: Natural Kinds in Metaphysics and Science* (Cambridge: MIT Press, 2011).

[394] See Bruno Latour. *Reassembling the Social: An Introduction to Actor-Network-Theory* (New York: Oxford UP, 2005); Timothy Morton. "The Mesh." *Environmental Criticism for the Twenty-First Century*. Ed. Stephanie LeManager et al. (New York: Routledge, 2011). 19-30.

Therefore, the central thesis that guides this chapter is that history, and the events that make up its development, is not constructed through the actions of social, technological, and natural objects working independently upon each other (particularly not humans acting alone upon the latter two). Rather, the events that produce the world are irreducible beyond the active relationships through which the events themselves emerge. History is concerned then with the "world whole" rather than the individual things that can only push and pull (or be pushed and pulled) on and by the bonds between them. These interconnections are the fundamental substantial cause of historical change; reality is relational and jointless. This view, whereby relations are *inherent* and have properties that do not "supervene" on, or reduce to, individual objects, has been referred to among philosophers of physics as *relational holism* or, more broadly, *ontological structural realism.*[395]

All three events concern pivotal moments in the 1990s through which Japanese bodies entered into the outer space environment. First, in 1990, the journalist Toyohiro Akiyama became Japan's first astronaut as he journeyed into space aboard the Soviet Soyuz transport vessel, a mission funded in part by the Tokyo Broadcasting Company. While in space, Akiyama looked back upon the "blue planet," a formative moment in his future worldview. Akiyama's descriptions of Earth from space form part of a larger pattern of the so-called "overview effects" that astronauts have experienced since breaking through the atmosphere in the 1950s. The overview effect itself provided a basis for astronauts to see the world as an interconnected whole of humans and nature together while also helping to catalyze the environmentalist movement later in the 20th century. Not only did the consequences of the overview effect generally help to

[395] See James Ladyman. "Structural Realism." *Stanford Encyclopedia of Philosophy*. Last revised 10 January 2014. https://plato.stanford.edu/entries/structural-realism/; James Ladyman, Don Ross, et al. *Every Thing Must Go: Metaphysics Naturalized* (New York: Oxford UP, 2007); Paul Teller. "Relational Holism and Quantum Mechanics." *British Journal for the Philosophy of Science, Vol. 37 Issue 1 (1986). 71-81.*

dissolve categorical separations, but Akiyama's experiences in those moments, the event of his looking back at Earth and talking about it, were enabled by an assemblage of forces involving a global discourse of "worldviews," modern communications technology, human cognition, and the inherent potency of Earth-space.

Also on that mission, scientists with Akiyama conducted a series of experiments on Japanese tree frogs, testing especially their experience of microgravity, and, through this, revealing the nature of their adaptions to gravity. Here, the line especially between nature and technology is blurred beyond usefulness as the frogs can be understood equally as technological artifacts and biological organisms. Not only were they both epistemic tools preserved and manipulated by scientists to gain insight into nature *as well as* fleshy organisms with a deep evolutionary past, but these two identities co-created each other and blended together. Moreover, the same evolutionary genealogy that made the Soyuz experiments equally parts technological and natural history applied to Akiyama as well, whose own body exhibited the same pattern of physiological response as the frogs'.

Finally, a few years later in 1997, Japan launched the Experimental Test Satellite No. 7 (ETS-VII or KIKU-7) from the Tanegashima Space Center. While in space, the satellite (named "Hikoboshi") was equipped with the first satellite robotic arm and conducted the first autonomous rendezvous docking operation with its smaller "target" satellite ("Orihime") two decades before I went to Zojo-ji on July 7$^{th}$, recreating myth as extraterrestrial engineering. The event received acclaim as an achievement of space robotics and foreshadowed the later development of the remote manipulator system (JEMRMS) aboard Japan's KIBO module on the International Space Station. The achievement also revealed a categorical break between humans and technology, as the control feedback loops that were required for the arm to function in outer

space effectively created a new kind of agent, one in which man and machine were only jointly autonomous. The arm was certainly not an independent being that acted on its own will, but it was neither a passive tool in the experimenter's hands. Additionally, it was the uninviting environment of outer space that has catalyzed the development of human cyborgs in order to function and bring humans into space under viable conditions. Outer space, as a cultural, geopolitical, and physical landscape, proved resistant to occupation by Japanese bodies, and the development of space robotics in Japan has worked to push through those barriers.

## Part 1: Toyohiro Akiyama Sees Earth from Space

> What is the most basic human activity? Eating. I wondered how seriously I had thought about the act of eating, or growing things that we eat. How do farmers think about the food they grow? And what role has rice farming played in the history of Japan? I felt I couldn't die without having some basic knowledge about these things.[396]

Toyohiro Akiyama replied with these words during a 2013 interview. At the time, Akiyama taught agriculture at the University of Kyoto while tending to his vegetable garden, applying his "journalistic drive for hands-on knowledge and experience" to this "most basic" activity. Earlier, Tomoko Otake asked Akiyama why he had so sharply changed his career path, after serving as a journalist for TBS for most of his adult life, eventually becoming the first journalist to report from outer space:

> The scenes I saw from 400 km above the Earth... what still struck me as impressive was the shining blue Earth, which looked like one form of life floating in the universe. At the same time, I was reminded of the thinness of the blue layer, which is the atmosphere. So it made me visually aware that the atmosphere is so thin, and such a thin atmosphere protects every living thing — forests, trees, fish, birds, insects, human beings and everything... As I watched the Earth from 400 km away, I looked back on the history of

[396] Tomoko Otake. "Toyohiro Akiyama: Cautionary Tales from One Not Afraid to Risk All." *Japan Times*. 3 August 2013. https://www.japantimes.co.jp/life/2013/08/03/people/toyohiro-akiyama-cautionary-tales-from-one-not-afraid-to-risk-all/#.XEdqes17nIU.

> mankind and thought about the repetition of activities that helped us grow, to now number 7 billion people... [397]

More than 20 years prior, in 1990, Akiyama became the first Japanese national in outer space, although Ellison Onizuka, a native-Hawaiian of Japanese ancestry, had flown aboard the Discovery five years prior.[398] His early transmissions from outside the atmosphere echoed these later memories: "This is Akiyama! The Earth is blue!"[399]

More humorously, Akiyama described a country that looked like "it has moss all over," except the northernmost island Hokkaido, which appeared to be "delicious kelp." Food, and the other physical connections our bodies remind us that we bear to the world, were never far from Akiyama's mind. At another point, he longed for *natto*, the infamously divisive Japanese soybean delicacy. At many points during the flight, Akiyama experienced the space sickness that so many astronauts encounter, and his viewers were privy to descriptions of the process of zero-gravity waste disposal. Before taking off, Akiyama had to kick his smoking and drinking habits during training, an addiction-laced deprivation which screamed through his on-air complaints. His first words upon landing were "I want a drink and a smoke," a conclusive reminder that spaceflight is perhaps most importantly a *physical* experience, entrapping our addictive sensuous desires as much as our imaginations.[400]

Japan's "first spaceman" on the whole has been forgotten. Japan's Aerospace Agency's (JAXA) brief official history found online of "Japan's manned space activities" excises his flight, and begins in 1985, when astronauts were selected by NASDA for a cooperative mission with the US called Spacelab-J. Unfortunately for NASDA, the Challenger Disaster of 1986

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[397] Ibid.
[398] See "Biography." *Astronaut Ellison S. Onizuka Memorial*. http://onizukamemorial.org/biography.
[399] Harvey. *Emerging Space Powers*, 105.
[400] Ibid.; David E. Sanger. "A Japanese Innovation: The Space Antihero." *New York Times*. 8 December 1990. https://www.nytimes.com/1990/12/08/world/a-japanese-innovation-the-space-antihero.html.

delayed the launch of Japan's first "real" astronaut, Mamoru Mohri, until 1992. Instead, the Tokyo Broadcasting System (TBS) celebrated its 40th anniversary by footing 1.2 billion yen to the Soviet company Glavcosmos to help fund the Soyuz TM-11 vessel's trip to the *Mir* space station, also buying a spot for one of their pioneering journalists. After passing through a selection and training process, Akiyama, who had worked as a correspondent in Washington and Vietnam before, shot into outer space aboard the Soviet vehicle emblazed with advertisements from Sony and Minolta.[401]

The opinion of some Americans seems to have been cynical. That December, David Sanger sarcastically wrote to the *New York Times*: "For those who complain that Japanese exploit Western technology without contributing much basic research in return, here are a few of this week's discoveries from Japan's first manned mission into space."[402] He goes on to document a variety of Akiyama's more asinine quips, while denigrating the unenthusiastic Japanese viewership and the scientific inefficacy of the experimentation on board.

More recent popular American accounts have also looked down upon the mission, variously playing into a "wacky orientalist" discourse that identifies Japan foremost with its essential oddness or identifying the event as "a living monument to the excesses of Japan's Bubble Era [a period of stock speculation, conspicuous consumption, and economic confidence in the 1980s prior to the asset bubble burst in 1992]," featuring a decidedly uncharismatic, chain-smoking idiot.[403] However, as space journalist Brian Harvey argues, these depictions are not fair:

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[401] Otake. "Toyohiro Akiyama"; Harvey. *Emerging Space Powers*, 103-105; "History of Japan's Manned Space Activities." *JAXA*. Last updated 7 June 2004. http://iss.jaxa.jp/astro/history_e.html.

[402] Sanger. "A Japanese Innovation." For a more neutral contemporaneous account, see Kathy Sawyer. "Japanese to Become First Journalist in Space." *Washington Post*. 12 November 1990. https://www.washingtonpost.com/archive/politics/1990/11/12/japanese-to-become-first-journalist-in-space/603c8136-c8b1-488e-be1d-47425bc8ea91/?noredirect=on&utm_term=.5e929f89ba62.

[403] See Sanger. "A Japanese Innovation"; Tom Hale. "The Bizarre Story of Japan's First Astronaut." *IFL Science*. 5 April 2017. https://www.iflscience.com/space/the-bizarre-story-of-japans-first-astronaut/; Matthew Alt. "Japan's Forgotten First Astronaut." *Neojaponisme*. 7 June 2011. http://neojaponisme.com/2011/06/07/japans-forgotten-

"Akiyama shot some of the best film ever taken of life on board *Mir*, conveying a sense of what most ordinary people must feel in orbit... TBS attracted record viewing figures during the mission. He came back with a stunning color film that made a first-class video."[404] Moreover, as will be seen later, the on-board experiments were of much greater scientific interest than such dismissals reveal. Most importantly here, Akiyama's experiences of seeing and describing Earth "from 400 km" off in outer space speak to a side of modernity that brought human consciousness of the ecological ties that bind humans to their natural Earth environment in an interconnected system to new heights. Moreover, they reflect the entangling relationships between human cognition, physical place, social discourse, and global communication systems that made such ecological thinking possible.

In 1987, three years before Akiyama caught sight of the "blue planet," Frank White published *The Overview Effect: Space Exploration and Human Evolution*. White's work popularized the phenomenon, the "overview effect," whereby astronauts experience a cognitive shift upon entering into space and looking back at Earth. The experience amounts to what later psychologists have described as a combined sense of awe and self-transcendence, the realization that the world is an interconnected (and fragile) whole, of which you yourself are a part, that is fractured only artificially by political rivalries. Overall, the overview effect spurs ecological and internationalist revelation.[405] This cognitive framework fits precisely with Akiyama's own experiences, of the Earth appearing as "one form of life," scarcely protected by the "thin atmosphere." White's account that "many astronauts return from space with an intense interest in

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first-astronaut/. For "wacky orientalism," see Wester Wagenaar. "Wacky Japan: A New Face of Orientalism." *In: Asia in Focus*, No. 3 (2016). 46-54.

[404] Harvey. *Emerging Space Powers*, 105.

[405] Frank White. *The Overview Effect: Space Exploration and Human Evolution* (Boston: Houghton-Mifflin, 1987). Esp. 11-13.; David B. Yaden, Johnathan Iwry, et al. "The Overview Effect: Awe and Self-Transcendent Experience in Space Flight." *Psychology of Consciousness: Theory, Research, and Practice*, Vol. 3 No. 1 (2016). 1-6.

ecology" is also reflected in Akiyama's own redirection of his lifestyle and interests as a result of his overview experience.[406]

In his book *The Ecological Thought*, Timothy Morton argues that individuals and scholars need to learn to "think past" the idea of nature.[407] There is no inside/outside relationship between human beings and their environments, and there are no discreet individuals that exist in isolation from the world around them. Everything is interconnected, and this realization, one that consistently tears around the edges of our basic metaphysics, is the essence of ecological thinking.[408] Ecology is about the relationships that constitute the world and ourselves. Moreover, as Morton makes clear, this kind of ecological thinking is only available in the modern era, even while modern dichotomies obscure access to it.[409] It is only with the deep knowledge that we have gained of biology and physics that the truly relational nature of the world can be appreciated. Additionally, the idea, or actuality, of viewing Earth from outer space is important for Morton's thinking: "seeing the Earth from space is the beginning of ecological thinking."[410] Ecological thinking is "totalistic" thinking, and seeing the "world whole," on a literal level, may be the most psychologically immediate and forceful trigger that the human mind needs to disintegrate dichotomies between individual and environment.

If the ecological thought and the overview effect are fundamentally modern creations, visions of the interconnected that rely on modern technology and science, then the belief that modernity can be essentially tied down to human domination of nature is called into question. Moreover, the popular perception that modernity has much to do with the invention of a "hyper-

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[406] White. *The Overview Effect*. 73.
[407] Timothy Morton. *The Ecological Thought* (Cambridge: Harvard UP, 2010). 5.
[408] Ibid, 1; 15; 33.
[409] Ibid, 4
[410] Ibid, 14.

separation" between nature and culture is in need of nuance.[411] Ian Miller offers a nuanced interpretation of what he refers to as "ecological modernity": the twin processes of "intellectual separation" from and "physical interpenetration" with nature. As people constructed ideologies of separation, modernity ultimately entangled people deeper and deeper in the web of nature.[412]

However, what the overview effect reveals is that modernity, however it entailed intellectual separation in some ways, could also catalyze ecological thinking that explicitly rejected separation. Far from modernity being fundamentally about how people have dominated the natural world, there exist potential narratives, such as the this one about the overview effect, about how people have come to realize that humans and nature are inseparable entities to begin with. The modern "worldview" is not necessarily a compartmentalized one, relying on strict dichotomies, and modernity may offer the cognitive capacity to see the world whole, as Culver put it, perhaps for the first time.

The overview effect certainly has much to do with human psychology, and from Frank White onwards, some have thought about ways that the human experience of the space environment elicits this effect. However, the overview effect is not an isolated phenomenon that exists in astronauts' brains; it is equally a social artifact born of decades of discursive developments of what "Earth from space" looks like. In fact, Timothy Morton's discussion of the topic homes in the imaginative constructs of those like John Milton and Percy Shelley, who imagined Earth from space far before orbital photography: "Earth's distant orb appeared / innumerable systems rolled / and countless sphere's diffused / an ever-varying glory."[413]

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[411] Bruno Latour discusses the project of modernity as one of "purifying" the realms of society and nature. *We Have Never Been Modern*. Trans. Catherine Porter (Cambridge: Harvard UP, 1993). 10-12. For the notion of "hyper-separation" as an endemic worldview of modernity, see Val Plumwood "Human Vulnerability and the Experience of Being Prey." *Quadrant*, Vol. 39 Issue 3 (1995). 34.

[412] Miller. *The Nature of the Beasts,* 3-4.

[413] Morton. *The Ecological Thought*, 22-24.

The conception of the whole world view as being one of humility, unity, wonder, and beauty are rooted in a deeper cultural past, one that cannot be reduced to Akiyama's one mind and physical environment. Dennis Cosgrove argues that the gaze from outer space, "which pulls diverse life on Earth into a vision of unity," is actually an artifact of the imagination of the early modern era as it is of outer space technology: "for all its radical newness, actually witnessing the globe culminates a long genealogy of imagining and reflecting upon the possibility of doing so. The meanings of the photographed Earth were anticipated long before the photographs themselves were taken."[414] Other scholars have recently followed in a similar vein: "The 'Earthrise era' [referring to the famous photograph of Earth from space taken in 1968] is but the tipping point of a long tradition of drawings, maps, and models."[415] Or, according to Hania Siebenpfeiffer in her essay on the pre-history of overview effects in 17th century literature: "the 17th century was also the time that provided us [with the] impressive visual semiotics and powerful aesthetics [that] still echo in our contemporary visual notion of Earth in outer space."[416]

While Akiyama's broader notions of how to conceptualize his experiences have had a deeper cultural background behind them, one specific description in particular speaks not only to the way that discourse on the whole world view had been globalized by the 1990s, but also to the way that man, machine, and nature co-produced Akiyama's experience. Yuri Gagarin, the first man in space, famously related to ground control in 1961 after entering space for the first time that "the Earth is blue."[417] Since then, the notion of the "blue planet" has become a constant

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[414] Denis Cosgrove. *Apollo's Eye: A Cartographic Genealogy of the Earth in the Western Imagination* (Baltimore: John Hopkins UP, 2001). ix-xi.

[415] Solvejg Nitzke and Nicolas Pethez. "Introduction: Visions of the 'Blue Marble." Technology, Philosophy, and Fiction." *Imagining Earth: Concepts of Wholeness in Cultural Conceptions of Our Home Planet*. Ed. Solvejg Nitzke and Nicolas Pethez (Verlag: Ruhr University, 2017). 10.

[416] Hania Siebenpfeiffer. "'Again the Earth (which ever I held in mine eye) did as it Were mask it selfe with a kind of brightness like another Moone': Inventing Blue Marble in 17th Century Literature and Astronomy." *Imagining Earth*. 133-134.

[417] See "The Earth is Blue." *BBC News*. http://news.bbc.co.uk/2/hi/science/nature/71662.stm.

motif, one that is reflected in both Akiyama's initial exclamation that "the Earth is Blue!" as well as his later description of the "shining blue Earth."

Mamori Mohri, the first official Japanese astronaut, describes a similar version of Earth:

> … It was so beautiful — blue and round. Just like Gagarin had said, it was a blue planet. I couldn't believe how beautiful it was. But the other thing I thought, when I looked at red areas of land like mountains, was that the Earth resembled cells seen through a microscope.[418]

In addition to reaffirming the organic holism associated with the overview effect, Mohri's description takes the blueness of the Earth as a central quality of Earth's appearance, one explicitly tied rhetorically to Gagarin's original description. In fact, Mohri specifically recalls his earliest desires of going into space as being linked with Gagarin's first mission:

> Mine was the generation that grew up watching the U.S. and Russian space programs develop. I was in junior high school when Yuri Gagarin became the first person in space... I still have a photo of me standing beside the television with Gagarin on the screen.[419]

Chiaki Mukai, another of the original NASDA 1985 candidate selections, describes similar formative experiences:

> Throughout my childhood, there were so many epoch-making events within the space program. For example: In 1961, when I was 9 years old, the Russian cosmonaut Yuri Gagarin orbited the earth and became the first human being to travel into space and return, to report about our "blue planet."[420]

The blueness of the Earth was not merely an immediate quality that naturally came to the forefront of Japanese astronauts' perceptions and found an obvious home in their words. Rather, the nature of these descriptions, and perhaps their perceptions, was prefigured by an earlier imaginative framework built-up through an exposure to Gagarin's globalized descriptions.

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[418] Edan Corkill. "Mamoru Mohri: A Spaceman Speaks." *Japan Times*. 4 October 2009. https://www.japantimes.co.jp/life/2009/10/04/people/a-spaceman-speaks-2/#.XEatQs17nIU.
[419] Ibid.
[420] Chiaki Mukai. "Space and I." *Global Education Magazine*. http://www.globaleducationmagazine.com/space-and-i/.

Akiyama's exclamation was more an explicit allusion to a larger familiar discourse than it was a self-made discovery. There is little doubt that Japanese astronauts would have seen that the Earth was blue regardless. In fact White tentatively suggests that the environment of outer space might even be especially conducive to clearer, starker vision.[421] However, that this description occupies such a key location in their experiences and especially their accounts is the result of cultural mediation.

However, culture, and specifically the spread of ideas, is not an abstract phenomenon. As in many cases, the globalization of the idea that "the Earth is blue" spread only by dint of modern communications technology. Mohri came to know about the "blue planet" through his television set, a memory that was then stored through photography. The TV was itself a symbol of modernization in Japan, one of the "three sacred treasures" of high-growth consumerism, alongside the washing machine and refrigerator. Just as Gagarin's discursive invention was diffused via televisions, radios, books, and newspapers, another aspect of the overview effect, its internationalism, was literally transmitted into Japan decades prior. Television played a crucial role in helping to foment that association between outer space and international unity that prompts Akiyama to so quickly turn from speaking of Japan to speaking "us," the human race, or that inspires Mohri to say that "when someone goes into space, they are going as representatives of the human race rather than of any single country."[422]

In 1969, the Apollo moon landing was broadcast in Japan. Takechi Kawai of the Mainichi newspaper wrote at the time that this broadcast "represented a moment in which people were able to think of themselves as human beings for the first time."[423] Certainly, the language of

[421] White. *The Overview Effect*, 31.
[422] Corkill. "Mamoru Mohri."
[423] Fumiaki Itakura "Television and Japanese Imagination of Outer Space." *Challenges of Space Anthropology, 2014-2015*. JAXA Research and Development Memorandum 14-012-E. 30.

the broadcast in Japan played into this perception: "Now, the day that a human being lands on the moon has arrived… The fact that men just like us are now working on the moon can be considered as being extremely significant for us, humankind."[424] As Fumiaki Itakura concludes:

> With the help of broadcasting satellites and a global system of television networks, the Apollo 11 media event in 1969 enabled people to feel as if they were experiencing the moment in real-time - that the whole world was connected with the moon - as they sat in their living rooms. In other words, the people watching the live television broadcast were able to share a sense of "unity" with audiences around the world.[425]

This image of the world as a unified whole was, like the "blue planet" discourse, a social construct inculcated within the Japanese public sphere, structuring the *episteme* of overview effects, the conditions for what could comprehensibly *be said*.[426] It was a situated perspective. It was also one that questionably homogenized the diverse experiences of humans into a single unified whole, forcing them all together into a single identity.[427] Takao Doi, the third 1985 candidate, speaks to this artifice clearly in describing part of his own overview effect in a very different tone:

> When I saw the Earth from space, it seemed to me that the entire globe was just one world. Actually, however, there are various countries, many kinds of cultures, and a variety of people living on the Earth. It is not possible to know what is happening on the Earth from space.[428]

However, understanding the overview effect as a socially constructed artifact need not abstract it from the material world, as was demonstrated in Chapter 2. Just as Doi describes the constraints that overview perspectives have on astronauts' epistemic abilities, these perspectives are also enabled by the inherent potential alive in Earth-space that *offers* these views up to those

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[424] Ibid, 32.
[425] Ibid, 32.
[426] On the *episteme* idea, see Michel Foucault. *The Order of Things: An Archaeology of the Human Sciences*. First published in 1966 (London: Routledge, 2004).
[427] Cosgrove's aforementioned book takes aim at this problem specifically.
[428] Takao Doi. "From Japan, Asia to the World – Forward to the Launch of 'MICHIBIKI.'" *JAXA Interviews*. 29 July 2010. http://global.jaxa.jp/article/interview/vol55/index_e.html.

like Akiyama. In Chapter 1, the notion of "cosmic geography" was utilized to describe the spatial relationships with Earth-space that contributed to the making of urban heat. In a similar fashion, the whole world view was a function of the spatial properties of Earth-space, the ones that allowed Akiyama to overview the Earth from 400 km.

The verb "offers" here is not used as a vague hyperbole here; in order to understand the overview effect, one must conceive of the world around us not as inert, but as an active force that exerts pressure on our perceptions of it. A central tenet of realism might be that the world constrains what we can say about it, that the world is not a formless clay shapeable by our minds, but maintains a deep interface with it. Frank White writes plainly that "mental processes and views of life cannot be separated from physical location. Our 'world view' as a conceptual framework depends quite literally on our view of the world from a physical place in the universe."[429] Our worldviews are therefore dependent on the cosmic geographic context we find ourselves in.

Modernity has been associated, most famously by Max Weber, with "disenchantment," the transition of humans' perception of the world from an "enchanted garden" into a rationalized, mechanistic universe. In her metaphysical defense of panpsychism, Freya Matthews similarly sees herself as breaking from an imagined modernity wherein the magic went out of the world and our engagement with it became damagingly instrumentalist. However, modernity also offered new routes of imaginative engagement with the world, as it gave these privileged few astronauts the ability to experience the world as animated and awakened.[430]

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[429] White. *The Overview Effect*, 3.

[430] Max Weber. *The Sociology of Religion*. 1st published in 1922 in German. Trans. Ephraim Fischoff (Boston: Beacon Press, 1991). 270; Freya Matthews. *For Love of Matter: A Contemporary Panpsychism* (Albany: State University of New York Press, 2003), esp. 15-22, 73-88. For a critical genealogy of the concept of disenchantment, see Jason A. Josephson-Storm. *The Myth of Disenchantment: Magic, Modernity, and the Birth of the Human Sciences* (Chicago: Chicago UP, 2017).

As many of the astronauts White interviewed described, none were fully prepared for what they saw from space, despite the growing cultural discourse of what it was *supposed* to look like: "if there is a common theme of astronauts' descriptions of changes in spatial perceptions, it is seeing the Earth from orbit and being emotionally unprepared for the experience."[431] Whatever images those astronauts like Akiyama, Mohri, Mukai, and Doi had absorbed from childhood onwards could not prepare them for the force that the world exerted on their senses. Alan Sheppard, the first American in space, describes how he had been "well-briefed on what to expect… But no one could be briefed well enough to be completely prepared for the astonishing view that I got."[432] In 1985, only 5 years before Akiyama's flight, Don Lind spoke to Frank White: "Intellectually, I knew what to expect. I have probably looked at as many pictures from space as anybody… So I knew exactly what I was going to see… But there is no way you can be prepared for the emotional impact… it brought tears to my eyes."[433] In fact, the very experience of "awe" that is so psychologically trenchant in the overview effect implies that is something that exceeds our conceptualizations. Akiyama's exclamation that the Earth is blue may have on some level been an attempt to re-inscribe the received *episteme* onto his overwhelming experience.

Rather than exhausting the material reality we encounter, our social constructs are in constant dialogue with it. Overview effects, like other perceptions or ideas, are formed at the interstices between ourselves and our environments. Akiyama's descriptions of Earth cannot be reduced to his own immediate experience of Earth-space, but neither can they be reduced to the technologically-diffused cultural ideas about what Earth is supposed to look like from space.

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[431] Ibid, 20
[432] White. "Interview with Alan B. Shepard Jr." *The Overview Effect*. 196-197.
[433] White. "Interview with Don L. Lind." *The Overview Effect*. 274.

Both are mutually dependent on each other to create Akiyama's own experience as he expressed it, an experience that blurred the "intellectual separation" between humans and nature that is supposed to be endemic to modernity. When Akiyama exclaimed that the Earth is blue, his words occupy a node in an assemblage of perceptions, natural forces, technological systems, and imagined ideas that formed an inseparable, evolving nexus, one that at that moment emerged into historical time as a recorded event.

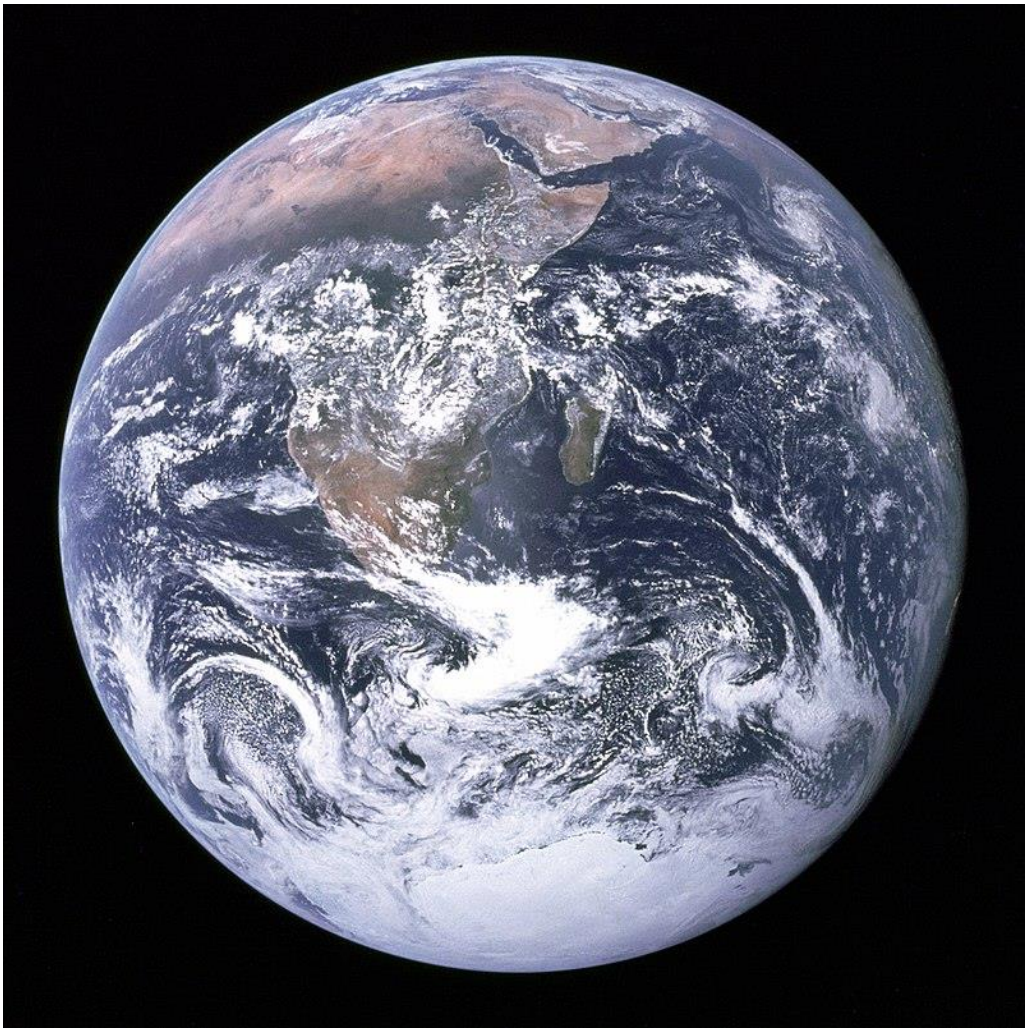

Figure 3.2[434]

[434] One of the most reproduced images in history, Blue Marble was taken first by the crew of Apollo 17 in 1972. "The Earth Seen from Apollo 17." *Wikimedia Commons*. https://commons.wikimedia.org/wiki/File:The_Earth_seen_from_Apollo_17.jpg.

## Part 2: Frogs in Space

Popular accounts in the US of the experiments carried out by Akiyama aboard *Mir* tend to be dismissive. Referring to the origins of the experiments as a school-proposed project, Sanger writes misleadingly that the experiment was "for schoolchildren." He continues sarcastically, writing that apparently "frogs' legs are fare for analysis."[435] Sylvia Hughes from *New Scientist*, while concluding that the frogs may be of scientific interest, quotes the head of the French laboratory that studied the frogs post-return: "'I think it was because frogs are sympathique. They have media appeal, take up little room and are very undemanding, as they need no feeding in space.'"[436]

In stark contrast, the final 1997 report from Masamichi Yamashita and his colleagues began as follows: "the "Frog in Space" (FRIS) experiment marked a major step for Japanese space life science." They go on to write that FRIS has been "the most extensive study to date of the behavior of any amphibian in microgravity."[437] According to the scientific communities that researched the responses of the Japanese tree frogs, as well as the numerous journals that published this research, frogs' legs, and many other parts of the body, were in fact fare for analysis. Most importantly, under the auspices of the Japanese Institute of Space and Astronautical Science, FRIS was an attempt to uncover the nature of evolutionary adaption to one of the most fundamental aspects of the Earth environment: gravity. As the report states in no uncertain terms: "since life first appeared on earth, gravity has been a constant selection force.

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[435] Sanger. "A Japanese Innovation."
[436] Sylvia Hughes. "Space Frogs' Bodies Donated to Science." *New Scientist*. 19 January 1991. https://www.newscientist.com/article/mg12917520-700-space-frogs-bodies-donated-to-science/.
[437] Masamichi Yamashita et al. "The Frog in Space (FRIS) Experiment Onboard Space Station Mir: Final Report and Follow-on Studies." *Biological Sciences in Space*, Vol. 11 No. 4 (1997). 313.

The behavior and development of all organisms consequently has gravity as an indirect, if not direct, determinant."[438]

The outer space environment, like the frogs, became an epistemic tool to be manipulated by scientists to turn gravity into an independent, controlled variable.[439] Behavioral changes induced in outer space microgravity, compared against similar induced behaviors on a control group on Earth, helped to reveal the determinant role of gravity on amphibian behavior and adaptive response. The frogs' bodies became a technology unto themselves, a tool that scientists *used* to uncover knowledge about natural history.

In order for the frogs to enter into and function in outer space, their bodies needed to be coupled with complex technologies that less provided life "support" than they did create organisms entirely dependent on human intervention to maintain their vitality. In space, there were no Japanese tree frogs, at least not as they subsisted on Earth, but a new object, a space frog. The space frogs that travelled with Akiyama were as much biological organisms as they were technical artifacts, whose *life*, a particular state of existence, was constituted in large part by a technological interface between the frog and the space environment.

Even prior to taking off, scientists began the procedures that would create space frogs out of the vulnerable, Earth-born biological material at their disposal. After catching 400 tree frogs from the Kanto region, only twelve optimal frogs were selected to be transformed on the basis of minimal injury, health, size, and weight. These frogs were then packed into plastic bottles and flown into Russia, from where the Soyuz vessel would take off. Prior to taking off, the frogs were starved for 10 days as there were worries that their feces might contaminate their launch container or block the air ducts. Other worries about chemical releases from the frogs were also

[438] Ibid.
[439] Ibid. "Access to space makes gravity a controllable experimental parameter."

addressed as absorbents were added to the transport containers.[440] In other words, the natural functioning of the frogs' bodies within their environment was not adequate for the procedures that space frogs needed to complete. In the latter case, changes to the frogs' immediate environment could contain the risks. In the former starvation case, however, it was easier to meddle with the frog' own bodies instead, withholding food in order to control their detrimental physiological mechanisms.

The frogs "prepped" for their journey in other ways: "it was examined whether treefrogs were adaptable or tolerable during spaceflight with support functions provided by the equipment. Mechanical vibration is superimposed on static acceleration at launch. Frogs were accommodated… They were exposed to random vibration and static acceleration up to 24 G."[441] While some of the available biological material that the frogs represented the engineers could adapt to with their technologies, other facts about the frogs were intolerable and needed to be adapted themselves. These preparations may not directly bear on questions of animal cruelty (as is noted, for example, the tree frogs can live naturally without food for a month).[442] However, these initial procedures do indicate a divide between the frogs and the space frogs and the technology that bridged the gap.

During and after take-off, technology played a vitalizing function. Just as our human skin plays a mediating role between most of our organs and our environments, playing a necessary role in making our bodies viable, the technology that was undetachable from the space frogs' ability to function was an intrinsic part of their *being*, as both a noun and a verb. At the launch

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[440] Akemi Izumi-Kurotani et al. "Space Frog Experiment Onboard Mir." *Journal of Space Technology and Science*, Vol. 6 Issue 2 (1990). 2, 4-5; Akemi Izumi-Kurotani et al. "Behavior of Japanese Tree Frogs under Microgravity on MIR and in Parabolic Flight." *Advances in Space Research*, Vol. 14 No. 8 (1994). 420.
[441] Izumi-Kurotani et al. "Space Frog Experiment Onboard Mir." 2.
[442] Izumi-Kurotani et al. "Behavior of Japanese Tree Frogs." 420.

stage, the six frogs were housed in Life Support Boxes (LSBs). The boxes sustained life by protecting the frogs from the more vigorous physical effects of launching, while also providing fresh air filters and a wet spongey lining. Additionally, the LSBs isolated the frogs from the crew members. While on board the space station, experiments were conducted on the frogs through glove bags that continued this isolation.[443]

While technology enabled the space frogs' existence, which was also in part constituted by human manipulation of normal amphibian functioning, the space frogs themselves became tools in the hands of Akiyama, manipulable space artifacts. According to the Tokyo Broadcasting System, the frogs were given "certain stimuli" to monitor their response.[444] The reports go into more detail:

> Behavioral responses at visual stimuli were recorded by showing specific objects and patterns… Mechanical disturbance was given by touching their back. Feeding behavior was examined by placing a live mealworm in front of the frog [the frogs were not fed regularly for subsistence, but only experimentally]. A piece of vinegar-immersed paper was planned to be placed on the dorsal skin of a frog for chemical stimuli.[445]

The list continues. Most importantly, it was not merely the case that the scientists manipulated the frogs' bodies in order to get more information about *them*. Such an interpretation seems to be suggested by Sanger's sarcastic explanation of the experimenter's goals. Rather, the frogs' responses, and the biology behind them, were merely extrinsically useful insofar as they hinted at broader evolutionary patterns that the micro-gravitational environment brought out.

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[443] Izumi-Kurotani et al. "Space Frog Experiment Onboard Mir." 2-4. There was additionally an analogous Frog Recovery Box (FRB) that was used for the return journey.

[444] Colin Burgess and Chris Dubbs. *Animals in Space: From Research Rockets to the Space Shuttle* (Chichester: Praxis, 2007). 346.

[445] Izumi-Kurotani et al. "Space Frog Experiment Onboard Mir." 1. For a similar list, see Akemi Izumi-Kurotani et al. "Space Experiment on Behaviors of Treefrog." *Advances in Space Research*, Vol. 12 No. 1 (1992). 264.

Perhaps the signature fact of the experiment was that, as the frogs floated through space, they extended their limbs outward and inflated their bellies in a "free-fall" posture. This pose is taken, especially by arboreal frogs, to reduce fall acceleration on Earth as they jump:

> Arboreal species that are free of surfaces treat microgravity as "free fall"… As a reflection of their adaptation to variable accelerations, they respond to free fall by taking a posture that would reduce their rate of descent in a stronger gravitational field… We view these frogs as having much natural experience with large and abrupt changes in acceleration as they fall or jump through the three dimensional world in which they live. This tolerance to changes in G is reflected in their behavior under microgravity.[446]

However, these observations are meant to reflect a larger picture of nature. As one report concludes: "comparative studies on interspecific variation in behaviors appears to be a powerful tool for examining the role that gravity plays in the living world."[447] Other reports similarly begin with broad references to the questions underlying these experiments: "the behavior of animals is one expression of their response to the environments of this planet. Gravity provides a dominant coordinate for the orientation behaviors of posture and movement."[448] The frogs themselves were only artificially the objects of the experiment. In reality, they are the "powerful tools" that, like microscopes, help to illuminate the true nature of what lies beneath, or, in this case, behind in a longer evolutionary past. After landing, the frogs were dissected to assess some of the physiological consequences of their flight. In addition to losing total protein, DNA, and calcium in some parts of their bodies, decreased and altered chemical activity was also found. In short, the space frogs did not revert completely to Earth frogs upon return.[449] After being

[446] Yamashita et al. "The Frog in Space (FRIS) Experiment," 317.
[447] Ibid, 318.
[448] Izumi-Kurotani et al. "Behavior of Japanese Tree Frogs." 419.
[449] Yamashita et al summarize the conclusions of these various studies ("The Frog in Space (FRIS) Experiment," 316).

transformed, sustained in the alien environment, and in some ways adapting themselves, the frogs remained artifacts of the space age.[450]

At a point during the experiments, one frog suddenly leapt out of sight and had to be recovered, prompting Akiyama to note: "Well, there you are, frogs are frogs, everywhere."[451] While at first pass, it seems as though the frogs were substantially and intrinsically altered to become pieces of technology, this analysis is inadequate as it does little justice to the inherent characteristics of the frogs that remained active throughout the experiments. Not only did the frogs maintain much of their essential naturalness in outer space, but these very qualities are what powered the experiments in the first place. The space frogs were only tools insofar as they retained much of their "frogginess" that could reflect back on the "living world." Moreover, as frogs, their biological nature was not exhausted by the experimenters' knowledge. For the experiment to work, it was necessarily the case that the frogs' nature could remain active. If the frog was a microscope of sorts, it was one that was not entirely created by the scientists, but merely reconfigured such that its own nature could be made useful.

In the history of life on Earth, gravity exerted at once a constraint on the kinds of bodies and biological systems animals could develop as well as an enabler that provided a constant environmental factor on which to base behavior. On the one hand, gravity restricted the early evolution of larger single-celled organisms, and, later on, forced organisms to grow skeletal systems to maintain movement, pushing them to adapt to survive under its "destructive

[450] For example, the frogs became able to ore quickly latch onto surfaces: "We interpreted this change as improved postural control by the frogs in microgravity and indicative of successful adaptation to the microgravity environment" (Yamashita et al. "The Frog in Space (FRIS) Experiment," 315).
[451] Burgess and Dubbs. *Animals in Space*, 346.

influence."[452] Blood circulation was one example of this constraint, as the relative positions of an animal's brain and heart had to be coordinated based on behavior to allow fluid to flow against gravity's pull in energy efficient ways.[453] However, gravity was not merely something that the living world had to "cope" with, "but was an environmental factor readily being available as an appropriate cue for orientation and postural control." All forms of life evolved with gravity as a constant, one that could be "transformed to a biological signal" as organisms adapted various mechanisms that used it as a way to maintain equilibrium.[454] Vertebrates, like humans and frogs alike, share inner ear structures known as otoliths that perceive gravitational acceleration and regulate balance.[455]

Often, gravitational zoology works as a subfield under astrobiology because outer space, as noted, can experimentalize gravity in unique ways. Experiments like FRIS therefore, are by their nature studies in evolutionary biology.[456] The behavior of space frogs, purportedly technological artifacts, is only explainable with reference to the ways their ancestors adapted to the fundamental forces of the universe. In microgravity, sensory cues for postural control do not match otolithic information transmitted on the basis of an expected gravitational environment, creating "intersensory conflict" that is conducive to motion sickness.[457] As was seen in *Mir*, the frogs' characteristic behavior of backward-bent, elongated necks and reverse walking was analyzed as motion sickness.[458] These experiments in microgravity are explained by distant

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[452] Ralf H. Anken and Hinrich Rahmann. "Gravitational Zoology: How Animals Use and Cope with Gravity." *Astrobiology: The Quest for the Conditions of Life*. Ed. Gerda Horneck and Christa Baumstark-Khan (Berlin: Springer-Verlag, 2002). 314-317

[453] Ibid, 316

[454] Ibid, 317

[455] Ibid, 321

[456] Ibid, 323. "… the aim of a large number of experiments using animals, particularly vertebrates, is concerned with the analysis physiology… in order to elucidate aspects of the role of gravity during evolution or/and to understand the effects of weightlessness concerning medical problems of human space exploration."

[457] Ibid, 322

[458] Yamashita et al, "The Frog in Space (FRIS) Experiment," 314-317

evolutionary responses to gravity. As such, the experiences emerge out of an assemblage of transhistorical relationships between the frogs' bodies, the technology that sustained them, and the humans that studied them, but also the basic gravitational environment of Earth and the adaptive force it exerted on vertebrate ancestors.

As Dipesh Chakrabarty has argued, the Anthropocene signals a new philosophy of history, one in which natural and human history must blend together to create useful explanations in the face of environmental change.[459] Edmund Russell's approach of "evolutionary history" has been one of the most powerful ways environmental historians have taken up this charge in the 21st century, using evolutionary biology as a lens through which to understand the adaptive pressures that humans have placed upon other organisms' genetic material.[460] In another vein, Daniel Lord Smail has advocated for what he calls "deep history," a *longue duree* approach that abandons the idea of "prehistory" and unites the history of the human species into a seamless narrative. As Smail writes, historians can look beyond written documentation: "… from artifacts, fossils, vegetable remains, phonemes, and various forms of modern DNA… Like written documents, all these traces encode information about the past."[461] As Timothy Morton puts it, "think of the rings of a tree. Your face is a map of everything that happened to it."[462] Just like the heat balance of contemporary Tokyo is a map of its urbanization patterns, the behavior of tree frogs in the microgravitational context is a map of its genetic history, a history embedded within the environment.

If the frogs' strange behavior is seen as historically rooted in both a deep and evolutionary history, the reading of space frogs as merely artifacts must be eschewed in favor of

[459] Chakrabarty, "The Climate of History."
[460] See Russell. "Evolutionary History."
[461] Daniel Lord Smail. *On Deep History and the Brain* (Berkeley: California UP, 2007). 6.
[462] Morton. *The Ecological Thought*, 68.

a more relational *identity*. It is not merely that the space frogs were *both* epistemic tools and squishy organisms, but that those identities were inseparable. To borrow a phrase form Timothy LeCain regarding human identity, the frogs were "natural-born" tools.[463] The frogs only functioned as tools, as windows on the past, because they themselves were its inheritors, whose naturalness inhered in their behaviors. Likewise, the space environment they were engineered into did not only *reveal* aspects of their biological nature, but it *instantiated* them as the frogs experienced a novel environment and even adapted to it in some ways. FRIS was as much a part of space history as it was of natural history. As such, that history is a balance of overlapping timescales, a "human history" imbricated within "physical forces, vast amounts of time, and the activities of non-human species."[464]

Referring to Akiyama's bout of space sickness, Sanger writes that "perhaps suffering from the same affliction that hit Mr. Akiyama, they have gone on an orbital hunger strike."[465] While the FRIS experiment was the first to include frogs in manned spaceflight, other frogs went into space in previous decades. In 1970, NASA launched the Orbiting Frog Otolith (OTO) mission carrying two bullfrogs. According to the final report, the test's purpose lay in:

> Studying in which way the lack of gravity pull will affect the functioning of that part of the [vestibular] labyrinth which controls balance by measuring the gravitational components corresponding to the different head positions, namely, the gravity sensitive or positioning receptors.[466]

Why bullfrogs? In an earlier technical report, the choice was made clearer:

> Gravitoceptors [develop] under a constant 1 G of stimulation… space flight and future missions on planets with different gravitational constants, have suddenly changed this situation. It will be of interest to study how sensors long adapted to a constant

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[463] LeCain. *The Matter of History*, 67-73

[464] Julia Adeney Thomas. "The Exquisite Corpses of Nature and History: The Case of the Korean DMZ." *Asia-Pacific Journal: Japan Focus*, Vol. 7 Issue 43 No. 3 (2009). 1.

[465] Sanger. "A Japanese Innovation."

[466] Torquato Gualtierotti et al. *Orbiting Frog Otolith Experiment (OFO-A): Final Report on the Data Reduction and Control Experimentation* (Milan: Piccin Medical Books, 1972). 1.

> environment will respond when the environment is radically changed… frogs are used on the assumption that no fundamental difference in the function of the otolith systems exist in amphibians and mammals.[467]

In these words, the core identity that is under study is not that of man or animal, but *vertebrate*, a class with one fundamental inner ear structure. More generally, space science involving animals has always been largely motivated by cross-species implications, as animals have been used as test subjects to generate information regarding risks that the human body may encounter.[468] When Sanger speaks of this "same affliction," he opens the door to a shared history between the tree frogs that Akiyama worked with and Akiyama himself, evolutionary threads that bind the world whole.

## Part 3: That Thou Art Mindful of Him

Isaac Asimov's short story "… That Thou Art Mindful of Him" takes one pass at dissolving the differences that distinguish man and machine. Like all of Asimov's "robot stories," the story revolves around the Three Laws of Robotics, which state, in sequence, that:

> 1. A robot may not injure a human being, or, through inaction, allow a human being to come to harm.
> 2. A robot must obey the orders given it by human beings except where such orders would conflict with the First Law.
> 3. A robot must protect its own existence as long as such protection does not conflict with the First or Second Law.

In the story's conclusion, two robots, both named George, contemplate the semantics of these laws, concluding that the authority they grant to human beings is only superficial. When two humans give conflicting orders, it is those of the more principled, rational one that they are to

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[467] Torquato Gualtierotti and D.S. Alltucker. "Prolonged Recording from Single Vestibular Units in the Frog during Plane and Space Flight, Its Significance and Technique." *Aerospace Medicine*, Vol. 38 (1967). 513-514.
[468] Burgess and Dubbs. *Animals in Space*, xxv-xxviii.

follow, and moreover, physical differences in sex or ethnicity bear no weight. Given that they themselves are surely more rational and principled than any human, all that lies in the way is those superficial physical differences between humans and robots. The laws are short-circuited, and the story concludes with the two plotting to overthrow human authority.

While the story pushes us to dissolve these lines, it reproduces them with our most cherished technophobic fantasy, what Asimov himself famously described as a "Frankenstein complex."[469] Published a couple years later, Asimov's novella *The Bicentennial Man* also seeks to dismantle the dichotomy, although this take replaces fear and stereotype with empathy and subtlety. The story follows an android, Andrew, as he progressively sheds parts of his robotic exterior to replace it with flesh and organs in the attempt to become more human. In the end, he replaces his positronic brain itself and becomes mortal. At first glance, the story is merely another anthropocentric fantasy, this time a "Pinocchio story" that imagines that all androids will be mysteriously driven to be become human, a story that only reaffirms our superiority to the rest of the natural and non-natural world.[470]

However, in the process, the story slowly attacks our notions of separation. In the transitional stages of transformation, as Andrew is a fully cyborgic system with conjoined human/robotic feedback systems, he begins to appear as much like a robot becoming more human as visa-versa. The transition begs the question: if Andrew at some vague point shifts from robot to human, by virtue of what does a life lived with a pacemaker or hearing aid fall squarely in the human category? While the dissolution of this distinction between man and machine can be run many ways, the case of robots is distinctly illustrating because, by most definitions, robots

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[469] For more background on this terminology see Ace G. Pilkington. *Science Fiction and Futurism: Their Terms and Ideas* (Jefferson, NC: McFarland & Company, 2017). 77-80.

[470] For both stories, see Isaac Asimov. *The Bicentennial Man and Other Stories* (New York: Doubleday & Company, 1976). 61-86; 135-172. For the Laws of Robotics, see p. 135.

are capable of a degree of autonomy as they interact with their environment. The long and complex history of space robotics opens the door to breaching the "steel wall, a mile high and a mile thick" that separates us from our "tools."[471]

In 1997. NASDA launched Experimental Test Satellite No. 7 (Kiku VII). The ETS-VII configuration consisted of two satellites in fact, a larger "chaser" satellite nicknamed Hikoboshi and a smaller "target" Orihime. In a series of experiments that began in 1998, Orihime would detach and the two would separate a certain distance before it was recaptured by Hikoboshi using a variety of automated sensors, GPS systems, and other partially autonomous and partially guided maneuvers. Three such experiments were conducted at increasing distances using different methods. In addition to these rendezvous docking tests, a series of experiments, completed in coordination with other international space agencies, were done to test the capabilities of the robotic arm system attached to the module.[472]

Both the docking and robotics tests were essential to Japan's future participation in the International Space Station, and both experiments proved highly promising. However, technical problems were encountered during the docking experiments. While the initial 2-meter separation re-docking went smoothly, the more ambitious later test of a distance of more than 500 meters proved more difficult. Various recapture mechanisms repeatedly failed as the satellites' thrusters failed and lost each other's respective positions. However, troubleshooting measures done on the ground were adaptive and successful as new software was remotely updated and the chaser

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[471] "Your brain is manmade, the human brain is not. Your brain is constructed, theirs developed. To any human being who is intent on keeping up the barrier between himself and a robot, those differences are a steel wall a mile high and a mile thick." (Asimov. *The Bicentennial Man*, 169).

[472] See Harvey. *Emerging Space Powers*, 90-91; Mitsushige Oda. "ETS-VII: Achievements, Troubles and Future." *Proceeding of the 6th International Symposium on Artificial Intelligence and Robotics & Automation in Space: i-SAIRAS 2001, Canadian Space Agency, St-Hubert, Quebec, Canada, June 18-22, 2001;* "ETS-VII (Engineering Test Satellite VII) / Kiku-7." *Sharing Earth Observation Resources*. https://directory.eoportal.org/web/eoportal/satellite-missions/e/ets-vii.

eventually reunited with its target 3 weeks later.[473] In both Japanese and Western media, the dramatic re-docking was celebrated as a major landmark in unmanned docking technology. Likewise, the engineers on the ground were "showered with rewards" from various robotics and engineering institutions. As Harvey writes, "the two years of ETS VII experiments were vital in laying the groundwork for Japan's participation in the International Space Station."[474] Scientific publications and reports also noted these successes, pointing for example at the realization of conceptual models of automated rendezvous technology: "the ETS-VII opened a very solid way to the autonomous target capture."[475]

While the ETS-VII module itself was unmanned, and the tests it underwent were similarly unmanned, its essential role in opening the door to manned Japanese spaceflight in the 21st century places the mission within the prehistory of the third tier of space power, where human bodies come to interact with the outer space environment. The rendezvous docking and robotics experiments were vital to servicing and conducting experiments on the later Japanese Experimental Module (JEM) or Kibo that constituted Japan's flagship effort on the ISS. The robot arm specifically served as a precursor to the successful application of the Remote Manipulator System used onboard Kibo to facilitate experimentation.[476] The technological capabilities developed, tested, and enhanced as a result of the ETS missions played a crucial role in enabling the occupation of outer space by Japanese bodies, both as a physical and natural environment as well as a cultural, geopolitical one.

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[473] Oda. "ETS-VII."
[474] Harvey. *Emerging Space Powers*, 90-91.
[475] Kazuya Yoshida. "ETS-VII Flight Experiments for Space Robot Dynamics and Control." *Experimental Robotics VII*. Ed. Daniela Rus (Berlin: Springer, 2001). 217
[476] Harvey. *Emerging Space Powers*, 90-91, 115-117.

The question of human occupation of outer space arose very early on in the history of spaceflight. In a 1953 article, "Man's Survival in Space," the *Collier's* magazine announced the only possible solution was to "bring our environment with us."[477] As such, human bodies would be maintained in the extreme environment by virtue of an oxygenated Earthly "container" that protected them from its elements. This approach was designed not to adapt to the outer space environment but to isolate oneself from it. In 1960, still before any humans had entered space, an opposing view was developed by Manfred E. Clynes and Nathan S. Kline:

> If man attempts partial adaptation to space conditions, instead of insisting on carrying his whole environment along with him, a number of new possibilities appear... What are some of the devices necessary for creating self-regulating man-machine systems? This self-regulation must function without the benefit of consciousness in order to cooperate with the body's own autonomous homeostatic controls. For the exogenously extended organizational complex functioning as an integrated homeostatic system unconsciously, we propose the term "Cyborg."[478]

"Cyborgs and Space" not only popularized this newfound terminology of hybridity that was subsequently stretched endlessly across scientific and humanistic disciplines, but also cleared the ground for a post-humanistic conception of the relationship between people and machines. While perennially controversial, the cyborg idea dissolves longstanding debates over the benefits of manned and unmanned spaceflight. As NASA has affirmed, the future of spaceflight is one of "robots and humans together."[479] However, this togetherness is not a mere cooperative relationship, but one much deeper that fuses the agencies of man and machine. The later robotics experiments conducted with ETS-VII begin to point towards this co-agential relationship.

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[477] Cornelius Ryan (ed.). "Man's Survival in Space: Picking the Men." *Collier's Weekly* (1953). 42. I was introduced to this quote and source in Maher. *Apollo in the Age of Aquarius*, 15.

[478] Manfred E. Clynes and Nathan S. Kline. "Cyborgs and Space." *Astronautics* (1960). 30-31.

[479] See Roger D. Launius and Howard E. McCurdy. *Robots in Space: Technology, Evolution, and Interplanetary Travel* (Baltimore: John Hopkins UP, 2008). xi. See p. xvii for the more recent "transhumanist and postbiological" interpretation of this "strangely prophetic" pronouncement of togetherness.

However, these relational agencies did not emerge merely out of the extreme physical environment that characterized outer space, but out of the international milieu Japan found itself in by the 1990s. In 1985, Japan was allowed participation in the American designed *Freedom* space station project, which would later evolve into the ISS.[480] Offered the opportunity to build the JEM module, NASDA went to work on its design immediately. The need to supply the module necessitated the creation of transfer vehicles that could dock autonomously with the module, using techniques developed during the ETS mission. Likewise, the Remote Manipulator Arm served as one of the essential components of the module as it would extend human capabilities to carry large objects and work effectively in the outer space environment. Here too, the ETS manipulator arm served as a conscious prototype for these more elaborate uses.[481]

As Harvey puts it, "for Japan, its own module offered the opportunity for permanent participation in manned spaceflight (albeit as a junior partner)."[482] As traced briefly in Chapter 2, the development of Japanese rocketry and spaceflight since the inception of its space program after World War II was highly constrained by both its technological gap as well as explicit international agreements with the United States that prevented indigenization of its technology. Concerns over Japan's subservience to the United States was a constant concern among NASDA leaders as well as skeptical US correspondents, like David Sanger, who questioned Japan's contributions. Geopolitically, Japanese participation in outer space was restricted.[483] More explicitly, the presence of Japanese bodies in outer space was circumscribed by the political setting. As part of the JEM program, it was required that one member of its crew of six always

[480] The ISS was in many ways a joint-product of US and Soviet invention and development that slowly emerged as the two countries combined efforts. For more on this history, see Jay Chladek. *Outposts on the Frontier: A Fifty-Year History of Space Stations* (Lincoln: Nebraska UP). 2017.
[481] Harvey. *Emerging Space Powers*, 90-91, 112-117.
[482] Ibid, 113.
[483] See especially Wray, "Japanese Space Enterprise."

be Japanese.[484] The outer space environment was also a political landscape, where international power balances determined the kinds of bodies that occupied the "last wilderness." Japanese entered into outer space only by virtue of its unequal partnership with the US, a partnership that catalyzed the development of space robotics in Japan in the 1990s in order to take advantage of the opportunities it was granted to gain access to an essentially Western space.

In addition to the international context of Japanese participation, subtler, harder to pin down, cultural and sociological factors determined the body politics of outer space. Chiaki Mukai, one of the earliest Japanese astronauts, explains that "it was in 1957 that the Russian Sputnik circled the earth. I was only five years old then. At that time almost no Japanese person was even aware of the space program..."[485] On the same note, Mamoru Mohri remembers that "[as a child] I also assumed it was only Americans and Russians who would go [into space]. I thought it had nothing to do with Japan."[486] The trailblazing astronauts of Japanese nationality grew up seeing outer space as an environment that was not "for them" in important ways. Despite all the internationalist and universalist inclinations of outer space discourse, the question of national identity did not disappear. As Mohri relates later in the interview in connection with a Japanese Antarctic rescue mission: "There was of course an element of pride... Japan had got there on its own steam."[487]

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[484] Harvey, 113.
[485] Mukai. "Space and I."
[486] Corkill. "Mamoru Mohri."
[487] Ibid. The Antarctic and outer space environment is quite similar in physical and international terms. Stephen Pyne places the exploration of both as part of the most recent "third age" of exploration. Both are hostile to human occupation. Moreover, the international order that has developed around Antarctica served as a model for space law. See Stephen J. Pyne. "Seeking Newer Worlds: An Historical Context for Space Exploration." *Critical Issues in the History of Spaceflight*. 29-35; Christy Collis "Res Communis? A Critical Legal Geography of Outer Space, Antarctica, and the Deep Seabed." *Palgrave Handbook of Society, Culture, and Outer Space*. 270-291.

While national identity played an important role in motivating early Japanese spacefarers, outer space was not merely an environment that was nationalized and politicized, but one that was importantly racialized. For all intents and purposes, outer space was a white space. As recent scholarship has explored, science fiction and popular media has historically reinforced a cultural imaginary of whiteness as the paradigm of space travel.[488] Outer space is presented as a space reserved for white men, and the positions those men occupy as heroes and conquerors are equally inaccessible to people of color. The racialization of outer space is also tied to its image as essentially as a wilderness, an analogy to those nature preserves on Earth that also have also historically excluded non-white people.[489] In reality, Americans of color naturally faced substantial barriers in accessing outer space, the space race emerging as it did during the Civil Rights Era. The first black astronaut flew into space only in 1983.[490]

Just as it has been constructed in fiction and reality as white, outer space is also gendered male, and scholars have also emphasized the social barriers that women have faced as aspiring astronauts. More specifically, scholars that have focused on this gender dynamic have pointed to the ways that science and medicine constructed women's' bodies as being unsuitable for the extreme environment of outer space.[491] Unfortunately, less work has been done on how body

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[488] See especially Sean Redmond. "The Whiteness of Cinematic Outer Space." *Palgrave Handbook of Society, Culture, and Outer Space*. 337-354. See Weitekamp for an overview of some of this scholarship (*Critical Issues*, 570-571). See also De Witt Douglas Kilgore. *Astrofuturism: Science, Race, and Visions of Utopia in Space* (Philadelphia: Pennsylvania UP, 2003).

[489] For a landmark paper on the historical link between the construction of wilderness landscapes and the destruction of Native land rights and populations, see William Cronon. "The Trouble with Wilderness, or Getting Back to the Wrong Kind of Nature." *Uncommon Ground: Rethinking the Human Place in Nature*. Ed. William Cronon (New York: Norton, 1996). 69-90. More recently, see Carolyn Finney. *Black Faces, White Spaces: Reimagining the Relationship of African Americans to the Great Outdoors* (Chapel Hill: North Carolina UP, 2014). For an overview of the literature on race and environmental history, see Connie Chiang. "Race and Ethnicity in Environmental History." *Oxford Handbook of Environmental History*. 573-599.

[490] Jenny Arena. "1983: First African American in Space." Smithsonian National Air and Space Museum. 13 August 2016. https://airandspace.si.edu/stories/editorial/1983-first-african-american-space.

[491] See Margaret A. Weitekamp. *Right Stuff, Wrong Sex: America's First Women in Space Program* (Baltimore: John Hopkins UP, 2004); Maher. *Apollo in the Age of Aquarius*, 137-182.

politics and race have interacted with regard to actual spaceflight. However, one brief, (frustratingly left uncited) aside that Harvey makes concerning the 1990 Glavcosmos selection process for the Soyuz mission suggests lucrative paths of historical inquiry: "Soviet doctors were adamant that they would not lower their standards [as they screened out potential Japanese astronauts] ... A particular problem for the Japanese was that 80% of the population have a deviated nasal septum; whilst the Japanese did not regard this as a problem, conventional Caucasian science was that this imperfection invited infection."[492] Outer space was a hybrid landscape, one blended together of social and natural characteristics, that systemically pushed Japanese to develop new relationships with technology in order to breach a series of physical, political, and cultural obstacles.

Once robotics helped to enable this breach, the most profound blending of agencies that the ETS mission catalyzed was a joint series of experiments between NASDA and the European Space Agency (ESA). These experiments were designed to test the robot manipulator arm and gain more experience and knowledge of experimental modes of human-robot interaction. In addition to experiments involving cameras and visual-based systems of control, the more intriguing experiment was the so-called "interactive autonomy" experiment. Under the interactive autonomy (IA) paradigm, robotic function is divided between the robot and the human operator along pragmatic lines between: "autonomous robot manipulations" and "robot-user interactions."[493] In short, the experiments were designed to allow for the bare minimum of human interaction, limited only to anomalous supervision and operational updating. Overall, the

[492] Harvey. *Emerging Space Powers*, 104.
[493] G. Visentin and F. Didot. "Testing Space Robotics on the Japanese ETS-VII Satellite." *ESA Bulletin*, No. 99 (1999). 1.

IA experiments co-produced by NASDA and the ESA were judged to be successful and useful in future application aboard the ISS.

However, it is not the case that interactive autonomy is merely a midpoint away from what roboticists refer to as a "master-slave" sort of interaction, whereby the robot is merely a tool, and toward "full autonomy" where there are two agents. Rather, interactive autonomy offers an avenue towards the relational agency. Modern technophobia in fact has in its background the same worldview that foils this thesis as a whole: that humans *use* technology instrumentally to control nature. Technology is thus a tool with no agency in its own right. The technophobia arises with the cognitive dissonance in picturing technology that is not inert. There is a dichotomy: if humans, technology, and nature carve the world at its joints, where do robots fall? If we imagine them not as our inert tools, they become humanlike, but not quite. Herein lies the "uncanny valley" within which androids are said to lie, the creepiness of near-human appearance. This perception lies in the way we divide humans and technology along active and passive lines as well as the way we conceive of agency as resting with individual, human will. To truly capture what the post-human world looks like, we must adopt a conception of robots beyond these background assumptions. As David Mindell has argued, we must look beyond the "myths" of robot autonomy (or instrumentality for that matter) and towards a "richer" picture of interpenetration.[494]

A robot, according to one influential review published only two years before ETS-VII, is "a machine which senses and acts upon its environment autonomously." In contrast, *teleoperation* consists in "a machine enabling a human operator to move about, sense and mechanically manipulate objects at a distance." However, this same paper later introduces the

[494] David Mindell. *Our Robots, Ourselves: Robotics and the Myths of Autonomy* (New York: Viking, 2014). 4-8.

notion of "shared control" that relates to open feedback loops running between the robot and operator, the latter issuing directions to the former while the former actively engages with its environment with sensors to send new information back to the operator, informing ongoing direction.[495]

Picking up on these ideas in a later 2016 paper, Kwang-Hyun Lee and colleagues develop a theory of "human interactive autonomy" and "shared teleoperation." While the robot arm aboard ETS-VII is a teleoperator that is controlled from the ground, the ESA/NASDA experiments were designed to introduce a degree of local autonomy into the system. The autonomy is radically shared, however, in the sense that it is distributed between operator and robot. Human intentions drive robotic goals, but the robot largely functions independently. However, human supervision is still required and is continuously updated by sensor feedback. Interactive autonomy moves beyond the myth, and its grounding grand narrative, by placing agency between the human subject and their machine partner. The human acts in the world through the feedback mechanisms that enable foresight and accurate guidance, while the robot acts through a combination of human direction and autonomous sensation. Interactive autonomy is relational agency.[496]

As the 1999 ETS report describes, "interaction is limited to the selection of activities, and related parameters, that the robot has to execute autonomously."[497] The directions and specifications are provided by human actors, but the actual activity is enacted by the machine

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[495] T.B. Sheridan. "Teleoperation, Telerobotics and Telepresence: A Progress Report." *Control Engineering Practice*, Vol. 3 No. 2 (1995). 205, 210.

[496] Kwang-Hyun Lee et al. "Development of Human Interactive Autonomy for the Shared Teleoperation of Mobile Robots." *RSJ International Conference on Intelligent Robots and Systems*. Daejeon Convention Center. 2016. 1524-1525. For a recent take on conceptualizing robot autonomy, see James M. Beer et al. "Toward a Framework for Levels of Robot Autonomy in Human-Robot Interaction." *Journal of Human-Robot Interaction*, Vol. 3 No.2 (2014). 74-99.

[497] Visentin and Didot. "Testing Space Robotics," 2.

within its environment, an environment that the robot, unlike the human, is embedded within. This environment is thus usefully cognized and synthesized by the robot before it is made available to human perception. If agency is understood as the ability to act within an environment, and if the robot's tasks are seen as an event, the agencies of the human and the machine are irreducible beyond the relationship that holds between the two. As Nicole Boivin writes, "if material is alive only because humans interact with it… it is also true that humans are alive only because they have material to engage with."[498]

Clynes' and Kline's original definition of "cyborg" may have been too strict. Given the similarities between interactive autonomous robotics and the extended mind concept, it is no surprise that the cyborg has attracted the attention of Andy Clark as well, who sees humans as "natural-born cyborgs" that exist in a *reality*, not just a science-fiction, of shared identities. While less radical, Clark's conception of the cyborg is more powerful and relevant, as an accelerating process whereby "our minds and identities become ever more deeply enmeshed in a nonbiological matrix of machines… when our technologies actively, automatically, and continually tailor themselves to us just as we do to them… the line between tool and user becomes flimsy indeed."[499] The semi-autonomous robot blurs this line better than most technologies, or at least more clearly, as it *reacts* to its environment that it senses with a capacity that is not programmed into many technologies.

Also important for Clark, though, is his distinction between "opaque" and "transparent" technology. The former "keeps tripping the user up" and tediously involves the user in the

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[498] From Nicole Boivin, quoted in LeCain. *The Matter of History*, 301. For the original, see Nicole Boivin. *Material Cultures, Material Minds: The Impact of Things on Human Thought, Society, and Evolution* (Cambridge: Cambridge UP, 2008).

[499] Andy Clark. *Natural-Born Cyborgs: Minds, Technologies, and the Future of Human Intelligence* (Oxford: Oxford UP, 2003). 12

process of operating it rather than providing an extension of the self into the environment. By contrast, in the latter case the "user sees through the tool and directly confronts the real problem at hand." The tool is completely integrated with the users' functions, making them suitable "technologies to bond with."[500] Compare this description to that offered by Lee in his description of ideal interactive autonomy: "it is still difficult to develop a shared autonomy, which can seamlessly collaborate with human operators… it was necessary to develop a method to improve the interactivity and adaptability of the shared autonomy."[501] This question of interface, of a seamless feedback-looped connection, lies at the heart of human-robot interaction studies.

Given the contemporary relevance of these problems, the transparency, and thus the cyborgic nature, of the ETS mission was constrained. The earlier 1995 report stated that "currently Japan might be said to be the leader in space teleoperator developments… The Japanese also plan a 'free flight' vehicle with a telerobot arm, scheduled for flight in 1997…"[502] This referred of course to the ETS-VII mission, a huge success that only furthered Japan's reputation as an international leader in space robotics. Whatever degree of dissolution ETS instantiated is debatable. However, the path that beckoned toward interactive autonomy and enmeshed human-machine relationships was readily apparent. It is true that the future of space will see robots and humans together, but not as distinct units of agency that exert independent force on the world, but as an unique contributors to an irreducible whole, a history powered by the ongoing relationships that constitute its structure.

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[500] Ibid, 35-36.
[501] Lee et al. "Development of Human Interacting Autonomy," 1524.
[502] Sheridan. "Teleoperation," 206. For reasons of concision and my own lack of background, I have not discussed the literature on robotics in Japan to much length. Those interested should see the recent work done by Jennifer Robertson and Yulia Frumer: Jennifer Robertson. *Robo Sapiens Japanicus: Robots, Gender, Family, and the Japanese Nation* (Berkeley: California UP, 2017); Yulia Frumer. "Cognition and Emotions in Japanese Humanoid Robotics." *History of Technology*, Vol. 34 Issue 3 (2018). 1-27.

**Conclusion: Extending the Earth**

In Ivan Tarkovsky's classic science fiction film *Solaris*, the plot follows a psychologist, Kris Kelvin, traveling to a space station. Aboard scientists had been observing the namesake planet, the station itself in disarray. Additionally, the scientists and Kelvin are disturbed by doppelgangers of past loved ones that the planet itself has created from their memories. During the film, one of the lead scientists, Snaut, rejects scientism and the value of objective knowledge: "Science? Nonsense… We have no interest in conquering any cosmos. We want to extend the Earth to the borders of the cosmos… We don't need other worlds. We need a mirror. We're in the foolish human predicament of striving for a goal that he fears, that he has no need for. Man needs man."

This message lies at the heart of the film. Solaris itself ultimately provides this mirror, as it merely reflects back the minds and desires of those on the spaceship. However, Tarkovsky suggests these ideas throughout. The occupants have extended the Earth most visibly by bringing aboard an abundant assortment of great books, paintings, antique furniture, and sculptures, making the setting appear more like a traditional French salon than a spaceship. The human experience has been selectively poached from Earth to be brought "to the borders of the cosmos." In another, poignant scene, Snaut explains to Kelvin that: "Night is the best time here. It somehow reminds me of Earth. Attach strips of paper to the air vents. At night it sounds like the rustling of leaves." [503]

What these brief anecdotes from *Solaris* reveal is that what it means bring Earth into space, a seemingly anthropocentric notion, is in fact a question of the relationships that people bear to the things around them. Human culture is not abstract, but deeply attached to those

[503] Viacheslav Tarasov. *Solaris.* DVD. Directed by Ivan Tarkovsky. First released in 1972 (Criterion Collection, 2011).

objects that form its essential medium, those minerals, rocks, and trees that are remade into high art. More deeply, what it means to be human, and feel human in such an inhumane environment, can be touched on by mimicking the sound of air and leaves. Man needs man, but man also needs the relational connections to the material world that make create and creatively sustain his humanity in the first place. Anna Tsing writes provocatively that "human nature is an inter-species relationship."[504]

"On August 21, 2013, a robot took one small step toward a brighter future for all."[505] These words were broadcast by Kirobo, the first robot to converse with a human in outer space, an achievement that landed Kirobo a Guinness World Record. The purpose of Kirobo, as part of the Kibo Robot Project, was to test the communicative potential of androids, equipped with facial recognition and language processing devices. Most importantly, Kirobo's purpose was to assuage loneliness, which can set in dramatically in outer space.[506] As the Kibo homepage puts it, with a flourish: "it carries on its small shoulders / hope for the future of humans living together with robots." The "vision": "Nowadays, more and more people are living alone… With a new style of robot-human interface, perhaps a way to solve this problem could be found."[507] According to one designer, "we wanted to send it into space to show that robots and human

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[504] Anna Tsing. "Unruly Edges: Mushrooms as Companion Species." *Environmental Humanities*, Vol. 1 (2012). 144
[505] Julian Ryall. "Japan's Kirobo Robot Takes 'One Small Step.'" *Telegraph*. 5 September 2013. https://www.telegraph.co.uk/news/science/space/10288058/Japans-Kirobo-robot-takes-one-small-step.html.
[506] Kevin Lynch. "Robot Astronaut Kirobo Sets Two Guinness World Records Titles." *Guinness World Records*. 27 March 2015. http://www.guinnessworldrecords.com/news/2015/3/robot-astronaut-kirobo-sets-two-guinness-world-records-titles-375259; Ben Woods. "How the World's First Robot Astronaut is Helping Pave the Way for the Future of Human-Android Interaction." *Next Web*. 26 March 2015. https://thenextweb.com/insider/2015/03/26/how-the-worlds-first-robot-astronaut-is-helping-pave-the-way-for-the-future-of-human-android-interaction/.
[507] "About the Kibo Robot Project." *Kibo Robot Project*. Toyota. https://toyota.jp/kirobo_mini/kibo-robo/en/project/.

beings… can go into a new era. It's a sort of symbolic project so people can understand how people can interact with robots."[508]

As Jennifer Robertson has argued, robotics in Japan serves in part as a conservative agenda to meet social needs with utopian technological fixes rather than deeper structural change in the society.[509] Nonetheless, the Project presents in stark relief what "bringing the Earth with us" can mean in the 21st century. However, it also complicates the picture. If it is true that we, in a way, live by and through our environments, they also live through us. The world, whether it is a semi-autonomous robot, a planet's appearance, or a frog's evolutionary history, speaks not only to us, but with us. Kirobo's first words upon landing too emerged from the nexus, words that echoed what generations of human astronauts had learned from each other and Earth-space: "From up above, the Earth glowed like a blue LED."[510]

[508] Woods. "How the World's First." Quoted is Communications Designer Yorichika Nishijima.
[509] Robertson. *Robo Sapiens Japanicus*, 1-32.
[510] Quoted in Lynch. "Robot Astronaut Kirobo."

## Conclusion: What the Fox Knows

In the introduction, I described the key contributions I hoped to make. Most importantly, I wanted to push historical scholarship beyond the outer edges of the discipline and its methodology and into the "orbit," if one can forgive the pun, of the vast world of human inquiry, in the natural and social sciences, in critical theory, in classic and contemporary philosophy. In doing so, I wanted to use these disciplinary frameworks to explore novel ways that we *relate*, in the now theoretically trenchant way, to the world around and within us. Moreover, I wanted to explore how the ways environmental historians think can be fruitfully extended into understudied topics. I was forced to rely on a broad range of literature to explore new fields, and in doing so, used the knowledge and concepts of those fields to enhance my environmental perspective. Additionally, I have tried to give a conception of *agency* that gives weight to the inherent potential of objects in the world while also giving relationships between them the driving role in historical change.

In smaller ways, I also hoped to demonstrate nuanced approaches historians could take to understand and work with scientific knowledge, both as an object of historical inquiry and as a tool of historical insight. I also sought to always give a global sense of history, never isolating Japanese history to the archipelago, but also showing the transnational connections that have always been so important to its modern history. Banking off of the material turn, I also hoped to never abstract too far away from the real *things* I wrote about, always trying in tried and true or innovative ways to integrate the material world into my analysis. Finally, I have tried to do all these things in outer space, a vitally important task so as to help develop ties between this niche subfield and the broader historical field, a task in which I am by no means alone.

Overall, I believe that two large impressions have emerged as I have written my thesis over the past year. First, as became most clear in the previous chapter, history must become posthuman. People are merely *one* aspect of what historians should study, and humans themselves cannot even be studied without engaging with the world they live in. Chapter 1 makes the point most strongly that in some historical events, humans are marginal actors in the first place. Historians need to make the transitional leap from seeing humans at the center of their work to seeing them as only one among many. Perhaps it will remain the case that humans will be at the start of any historical inquiry; we are no doubt most interested in ourselves. However, they cannot be the sole middle or end of any historical narrative. No matter what the topic is, humans never exist abstractly. We must not relegate these other topics to other disciplines, but must take the dive into the rest of the world.

To do this, an interdisciplinary approach as I have given here is not only useful, but essential. Historians should forget, at least sometimes, that they must think of themselves as *historians*. For most of my undergraduate career, I have been told that there is something called 'thinking like a historian,' and that this is the key to good history education. I do not really believe that there is such a thing, or that there should be. What makes history such a powerful discipline, and why I find a home in it, is not that it offers a unique perspective on the world, but that it is elastic enough to draw from everything around it to offer compelling explanations of that world. As Paul Feyerabend advocated for the sciences, historians can adopt a radically pluralist "epistemological anarchism" that looks more towards the importance of the results for, following Haraway, providing *better* accounts of the world, than any adherence to principled

ways of getting them.[511] If historians can shed their ideas of what the proper method of historical research is, I believe there is great potential to make history more meaningful for everyone.

Secondly, I believe that historians must become comfortable with a multiplicity of narratives that do not necessarily stand easily beside one another. Nowhere is this tension clearer in my thesis than with my use of the term *modernity*. In his philosophical work, Ludwig Wittgenstein promoted what some have termed an "antiphilosophy." He believed that philosophers often got themselves into apparent problems only because they attempted to elevate ordinary language to a technical vocabulary through which all confusions could be laid to rest. Rather, the confusions only multiplied. Historians are often guilty here as well, and the always shifting attempts to define modernity are a key example.

Wittgenstein also railed against semantic essentialism, the belief that the objects that a term picks out all share in one essential feature by virtue of which they are named. Rather, he coined the term "family resemblances" to describe how terms extend their use beyond any essential element to capture a diverse array of objects. While three things might all be called a "game," for instance, it is not necessary that they all share one feature. Rather, via family resemblance, one game might have features A, B, and C, another might have B, C, and D, and a third might have C, D, and E. By the end, games one and three don't bare any commonality, but are linked by the referent between them that allows them to be captured in the overlapping, threaded tapestry of meaning.[512]

When we use a word like "modernity," we *already know* what we mean because the meaning is not metaphysical, but social, essentially connected only to the way it is used. In

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[511] For epistemological anarchism, see Paul Feyerabend. *Against Method*. 3rd Edition (London: Verso, 2002).
[512] See Michael Forster. "Wittgenstein on Family Resemblance Concepts." *Wittgenstein's Philosophical Investigations: A Critical Guide*. Ed. Arif Ahmed (Cambridge: Cambridge UP, 2010). 66-87; Alan Badiou. *Wittgenstein's Antiphilosophy* (London: Verso, 2011).

general language, I take it that modernity picks out something to do with the recent past, something about it that marks it apart from the time before it. Often, it has something to do with scientific rationalism, capitalism, and the nation-state. When we attempt to define modernity more precisely, we are *not* better describing what the word *really* means, but we are getting caught in a knot of technicality that itself invites debates and problems.

In this thesis, I have used modernity to loosely refer to things that I believe are generally taken to be "modern" in common usage, and my hope is that none of my references have been confusing or obscure. Historians and philosophers alike may be too ready to try to give useful definitions of concepts where they might be better served by leaving terms to float within language naturally, offering instead *substantive* histories of what actually happens in the world. My thesis does not an attempt to define modernity; I believe that the grand narrative I am attacking itself relies on a loose conceptualization of it. While the analytic philosophy that has become the norm in the Anglophone world in the 20$^{th}$ century has done much to clarify our concepts and precisify our analyses, we should not get caught too deeply in the language games it elevates.

I have likewise steered away from defining one of my core subjects: *nature*. I simply never felt the need to do so. In a real way, we already know what it means. What I believe *is* obscure, and what is at the heart of many debates, is how we think the things it refers to relate to one another or humans, and *this* is why I did attempt to offer a more substantial definition of *agency* instead, a term that I believe does in fact pick something out in reality, a fundamental property (or "joint") of the universe, albeit a relational one. Paul Sutter argues that environmental historians should be wary of the very concept of agency, following Linda Nash in her mistrust of borrowing conceptually from social historians. However, Nash also argues that environmental

historians are "uniquely positioned" to reframe agency in a way that moves away from the notion that agency "concentrates a vast amount of power in a supposedly rational center."[513] Rather than coming up with new terms, I have tried to rework agency into a relational model, following on the heels of actor-network theorists among others. This conception of agency is at least somewhat responsive to the deep concerns, articulated by Walter Johnson, that 'agency' has become a dangerous abstraction that separates human beings from the "specific political and cultural contexts of their actions."[514] While relational agency is itself perhaps a *global* concept applicable to many different narratives, it is not itself a grand narrative because it is only vague until it gains substance through the particular social and material circumstances to which it is applied.

In the interest of tying the chapters together, however, it is also important to avoid an overly anthropocentric interpretation of relational agency. As I hoped to show in Chapter 1, interactions often take place among nonhuman individuals, and these interactions also cause change over time. Relational agency is not merely a way to tie humans and nonhumans together in history because nonhuman forces create change amongst themselves as well; hybridity is often the *material hybridity* Brett Walker writes of.[515] Nash's call to disperse agency between humans and nonhumans is not radical enough, and if in Chapter 1, I put too much emphasis on the power of discreet *things* like concrete, the answer is not necessarily to always throw humans back in the agential network. While this thesis has developed towards a more holistic picture than Chapter 1 suggested, I do not intend to back off from the central claim of Chapter 1, that human agency

[513] Sutter. "The World with Us," 97-99; Nash, "The Agency of Nature of the Nature of Agency," 68. While Sutter argues that "*agency* suggests a kind of causal equivalence… that environmental historians must move beyond," he goes on to cite this same argument from Nash concerning the environmental historians' ability to *rework* agency into history in innovative ways.
[514] Walter Johnson. "On Agency." *Journal of Social History*, Vol. 37 No. 1 (2003). 114-115.
[515] See footnote 158.

was a peripheral force in the development of heat islands, which arose far more from the relationships (and the relational agency) that emerged outside of human thought, culture, and intention.

One danger that Paul Sutter worries about is that if environmental histories become too hybrid they will lose their sociopolitical purpose; they will cease to *matter* within a "haze of moral relativism."[516] Attached to this concern is the problem of blame and responsibility. If environmental histories take away localized human agency, who can we blame for environmental injustice or global warming? It is just this worry that Andreas Malm presents in his polemical attack against new materialisms like those articulated by Timothy LeCain and Jane Bennett: "In climate politics, singling out the root cause is not a matter of intellectual satisfaction. It is a matter of life and death… When it comes to negotiating who should cough up money for the loss and damage wrought by climate change, it will all be a question of responsibility."[517] I believe that this worry sits on two assumptions that, if dissolved, relieve a large amount of ethical distaste in hybridity paradigms.

The first is metaphysical. Those who advocate for social justice often blame *systems* of power, like capitalism, that have *caused* these problems. However, hybridity does not disallow such blame as long as we acknowledge that capitalism is not a purely human system. Rather, as has been fleshed out by others, modern industrial capitalism is closely tied to the "physical properties" of fossil fuels and the energy regimes that are built around them.[518] In renaming the Anthropocene the "Carbocene," Timothy LeCain does not seek to overlook the importance of

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[516] Sutter. "The World with Us," 119.
[517] Andreas Malm. *The Progress of This Storm: Nature and Society in a Warming World* (London: Verso, 2018).
[518] Elmar Altvater. "The Social and Natural Environment of Fossil Capitalism." *Socialist Register*, Vol. 43: Coming to Terms with Nature (2007). 41. For an innovative and influential analysis of how the nature of fossil fuels enabled and constrained the development of capitalist democracy since the industrial revolution, see Timothy Mitchell. *Carbon Democracy: Political Power in the Age of Oil* (London: Verso, 2011).

capitalism, but to ground the nature of capitalism in material reality.[519] As Bathsheba Demuth puts it in a recent article, "modern, growth-oriented states do not just change or provoke nature. They themselves function ecologically, sunk into and thus governed by the *distributive agency* of entire ecosystems" (italics mine).[520]

While Malm argues that *intentionality* must be at the center of a responsible notion of agency, intentions are merely one property some beings have. Sometimes they play an important role in changing the course of events and other times they have little importance. Never do they alone cause things to happen, and if we limit agency to intentionality then we need a new term to encompass how assemblages of properties and forces can actually make things happen. Finally, on a different note, while Malm himself argues that we need to train our attention at the *system* of "fossil capitalism," focusing too much on intentions handicaps a social justice movement aimed at the structural problems with the world. As Ta-Nehisi Coates writes in the context of racism, "the point of this language of 'intention' and 'personal responsibility' is broad exoneration… 'Good intention' is a hall pass through history."[521]

The second is more directly ethical. In our moral outlook, we tie *causation* and *responsibility* too closely together, such that we believe that in order to put those in power to task we must find them to be the root cause of injustice. However, responsibility can also be read as a function of power itself, as a matter of bearing a special relationship to injustice. Those who have social and economic power are responsible for environmental injustice simply due to the fact that they have greater ability and opportunity to alleviate the injustice. Once we materialize the

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[519] LeCain. *The Matter of History*, 311-328.
[520] Bathsheba Demuth. "The Walrus and the Bureaucrat: Energy, Ecology, and Making the State in the Russian and American Arctic, 1870-1950." *American Historical Review*, Vol. 124 No. 2 (2019). 487.
[521] Ta-Nehisi Coates. *Between the World and Me* (New York: Spiegel and Grau, 2015). 33. See Malm. *The Progress of This Storm*. For his earlier work, see Andreas Malm. *Fossil Capitalism: The Rise of Steam Power and the Roots of Global Warming* (London: Verso, 2016).

systems and structures we seek to blame and place responsibility on powerful individuals simply due to their relative positions within those systems, then the moral discomfort with hybridity and relational agency loses at least some of its force.

Whether we call things 'nature' or not matters little. What really matters is how we think *those* things interact with other things and each other. Paul Sutter has argued that environmental historians should be wary of, in a memorable phrase, "waving the muddy shirt," merely arguing that 'nature matters' as an axiomatic principle. They should instead point to particulars. He concludes one essay: "it is not merely that 'nature mattered' to the Civil War. It is, rather, that environmental history can be a powerful way of rethinking the very *matter* of the war, its lived material realities, and their formative relation to that roiling ideological formation that we call nature."[522] When dealing with particulars, like sunlight, concrete, frogs, the outer space environment, satellites, earthquakes, or planetary discourses, the mere "roiling" categories we place these things into are not as historically important as the way particular things enter into co-agential relationships. Perhaps there is a way to define modernity or nature that offers more than it obscures and misleadingly homogenizes or distinguishes, but that is a task for another historian.

More broadly, these big ideas tend to lead us right into grand narratives. Once we believe we need to give essential qualities to *nature* or *modernity*, we begin to think that these things have one history. In this thesis, I have instead presented many modernities (and arguable many natures), associated with urbanization, meteorology, outer space and more, that do not

[522] Paul Sutter. "Epilogue: Waving the Muddy Shirt." *The Blue, the Gray, and the Green: Toward an Environmental History of the Civil War*. Ed. Brian Allen Drake (Athens: Georgia UP, 2015). Sutter makes similar points in "The World with Us."

necessarily relate to a big, or as Dorothy Ko puts it more dramatically, "gigantic" history.[523] Even if we accept that only one, real world exists, we should not be tempted into thinking that history can or should try to offer one history of it. Rather than a view from nowhere, we should, again as Haraway suggested, integrate many situated perspectives into our worldviews. Rather than forcing them all together in one narrative, each can be given its own due within a pluralistic, even *incoherent* in the literal sense, mosaic of refracting stories. After all, the fox knows many things.

[523] Dorothy Ko. *Cinderella's Sisters: A Revisionist History of Footbinding* (Berkeley: California UP, 2005). 12; I use the term "many" instead of "multiple" as the latter is used to push explicitly against a modernization theory picture that imagines a teleological progression of civilization from West to East. "Multiple modernities," in contrast, is a different narrative that sees different locations as moving towards their own individualized modernity. As I argued in Chapter 1, this early modernization theory should not be altogether thrown out as it is important to see the technology and material transfer that I discussed there as largely asymmetric and uniform. As such, I use "many" not to give a different meta-narrative, but simply to ease away from the need for a meta-narrative at all. See S.N. Eisenstadt. "Multiple Modernities." *Daedalus*. Vol. 129 No. 1 (2000). 1-29.

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